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**Gehani et al.**

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(45) **Date of Patent: Oct. 20, 2015**

(54) **CONFORMANCE PROTOCOL FOR HETEROGENEOUS ABSTRACTIONS FOR DEFINING USER INTERFACE BEHAVIORS**

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(73) Assignee: **Apple Inc.**, Cupertino, CA (US)

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(21) Appl. No.: **13/231,762**

(22) Filed: **Sep. 13, 2011**

(65) **Prior Publication Data**

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(51) **Int. Cl.**

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***G06F 3/00*** (2006.01)
***G06F 9/44*** (2006.01)
*G06F 3/0481* (2013.01)

(52) **U.S. Cl.**

CPC .. ***G06F 3/00*** (2013.01); ***G06F 8/34*** (2013.01); *G06F 3/04817* (2013.01)

(58) **Field of Classification Search**

USPC .................................................. 715/762, 763
See application file for complete search history.

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*Primary Examiner* — Dino Kujundzic
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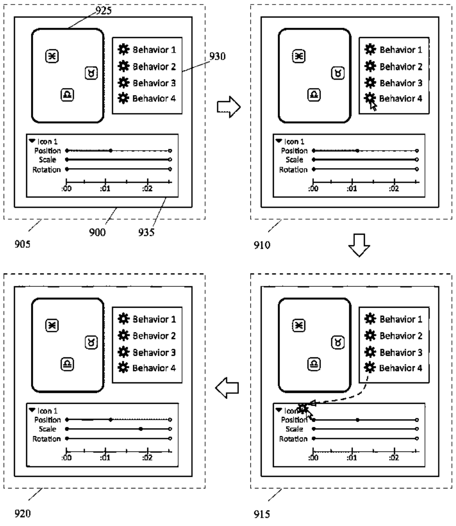
(57) **ABSTRACT**

An authoring system for building an application that has a set of graphical objects and is for performing several operations on several graphical objects in response to several user interaction events. The authoring system includes (1) a first set of tools for defining a first description of a first operation that is to be performed on a first graphical object and (2) a second set of tools for defining a second description of a second operation that is to be performed on a second graphical object. The second set of tools provides at least one different tool for defining the second description than the first set of tools provides for defining the first description. The authoring system also includes a conformance module for modifying at least one of the received descriptions to ensure that the descriptions of both the first and second operations are in a uniform description format.

**18 Claims, 25 Drawing Sheets**



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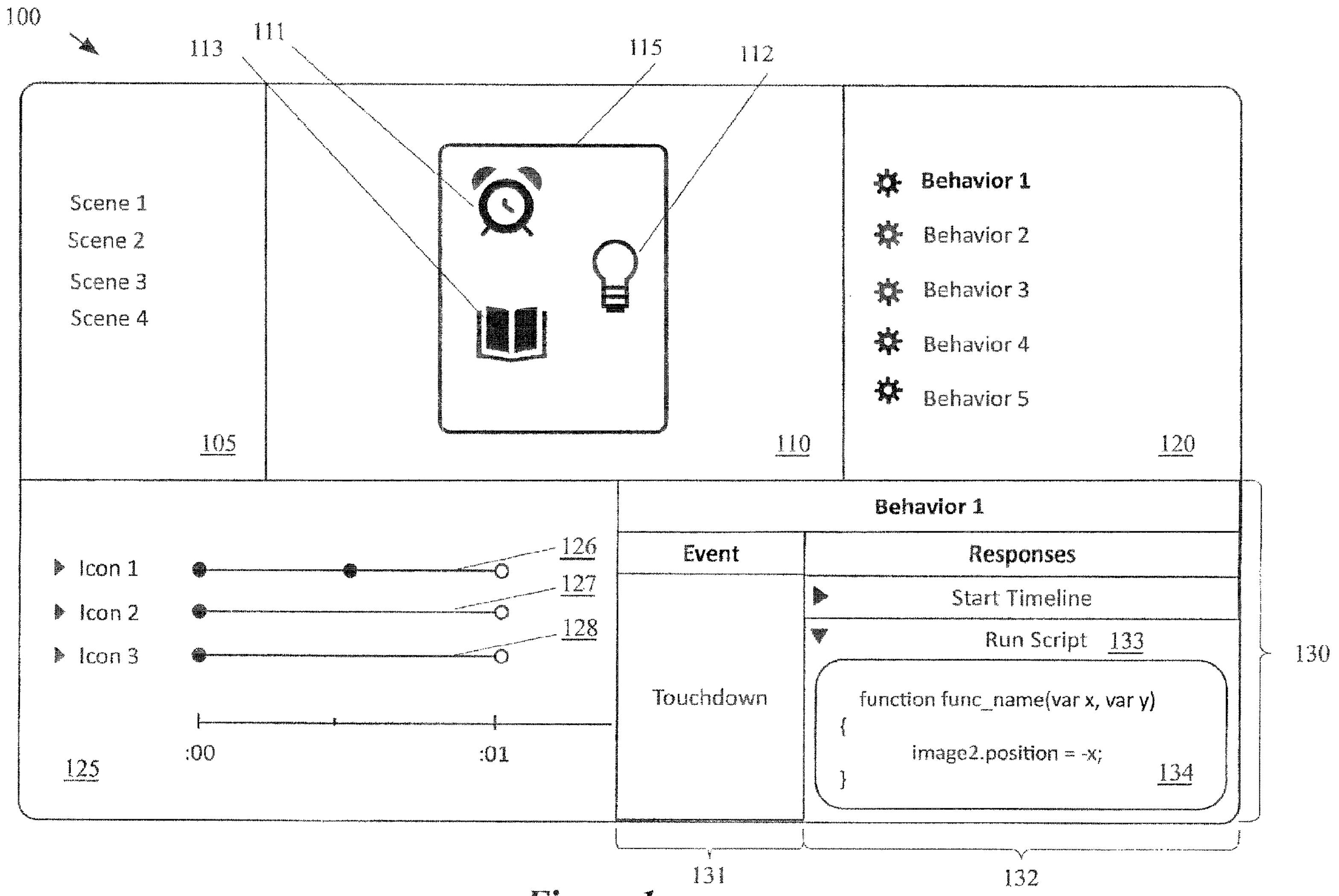


```
function func_name(var x, var y)
{
        image2.position = -x;
}
```

*Figure 1*

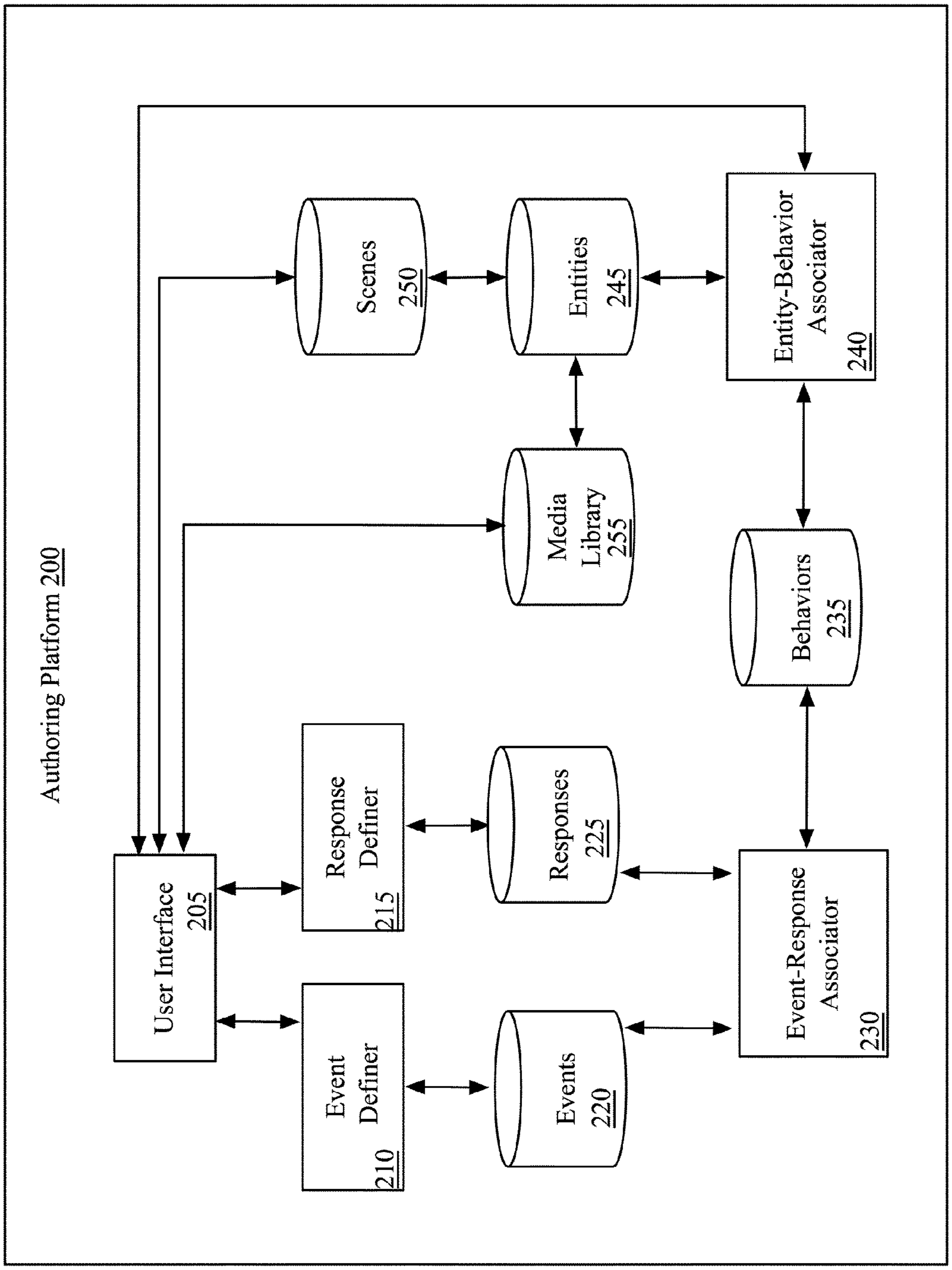

Authoring Platform 200
User Interface 205
Event Definer 210
Response Definer 215
Events 220
Responses 225
Event-Response Associator 230
Behaviors 235
Entity-Behavior Associator 240
Entities 245
Scenes 250
Media Library 255

*Figure 2*

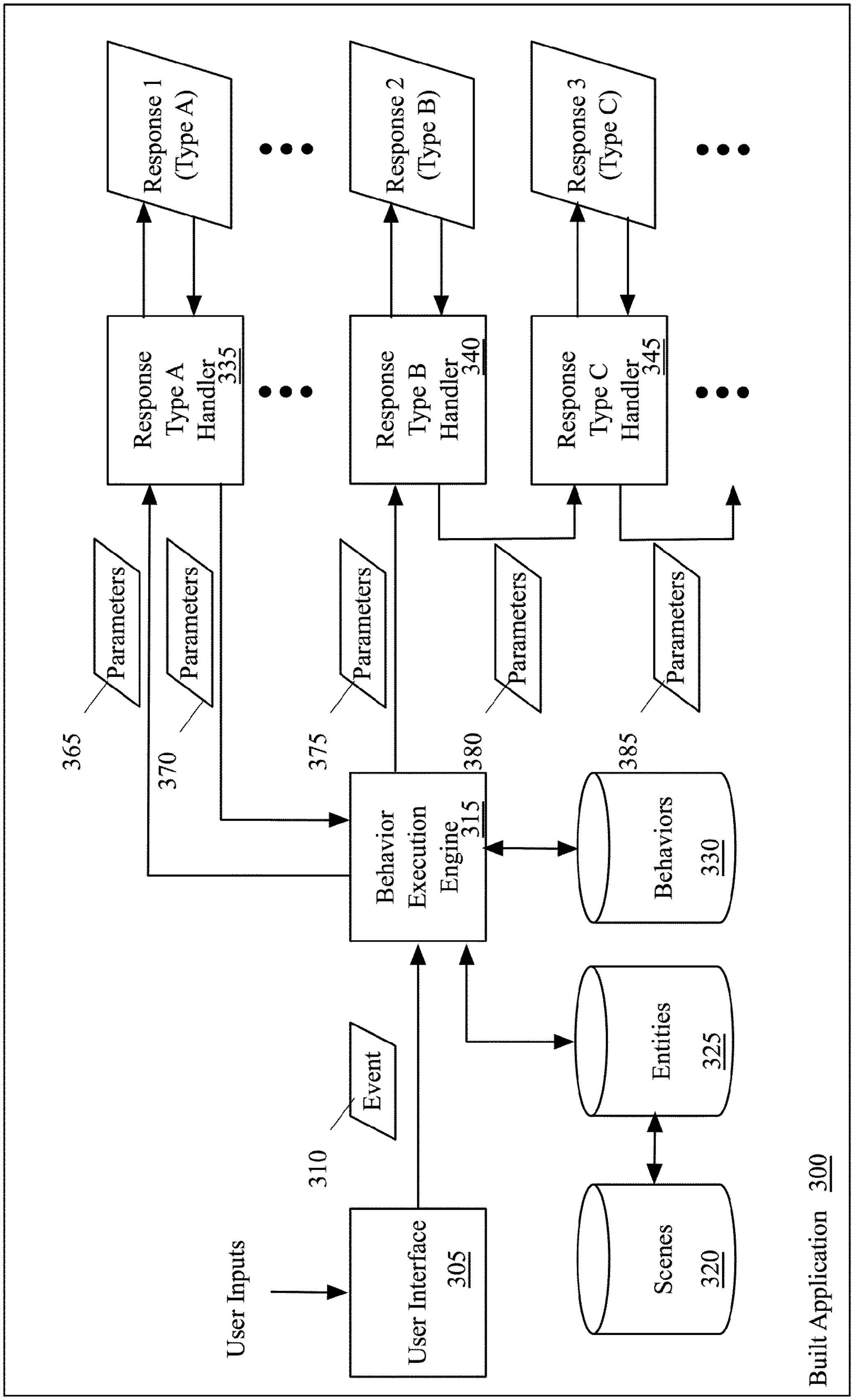

User Inputs
User Interface
305
310
Event
Behavior Execution Engine
315
Scenes
320
Entities
325
Behaviors
330
365
Parameters
370
Parameters
375
Parameters
380
Parameters
385
Parameters
Response Type A Handler
335
Response Type B Handler
340
Response Type C Handler
345
Response 1 (Type A)
Response 2 (Type B)
Response 3 (Type C)
Built Application 300

*Figure 3*

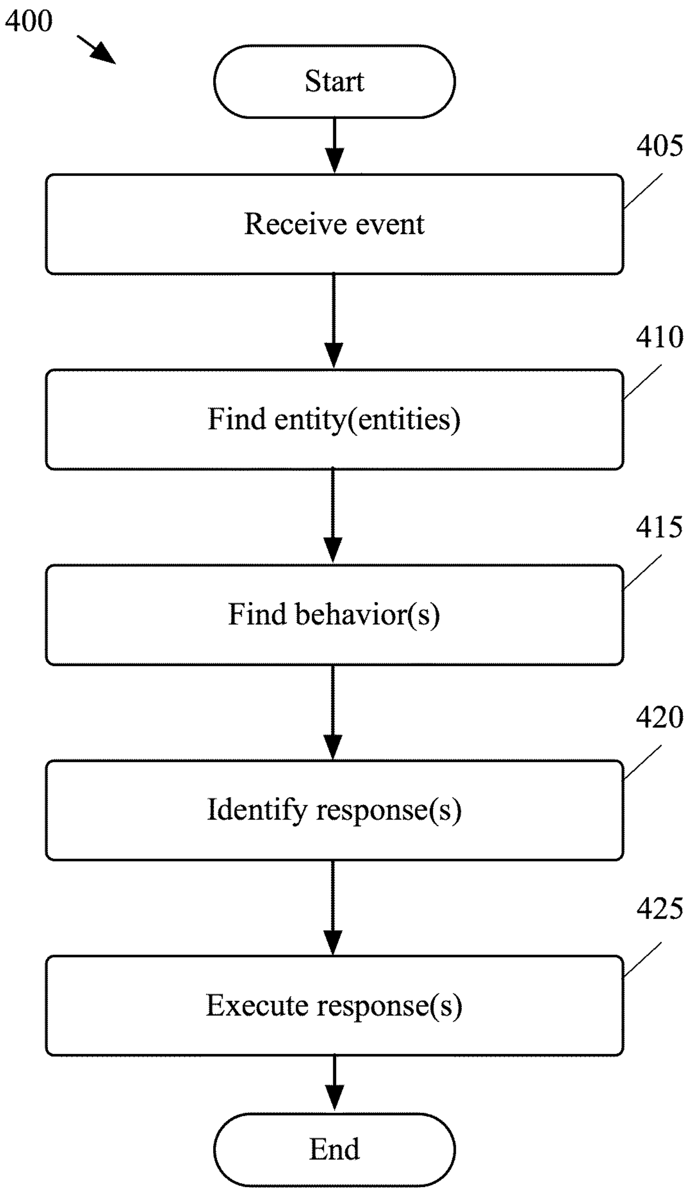
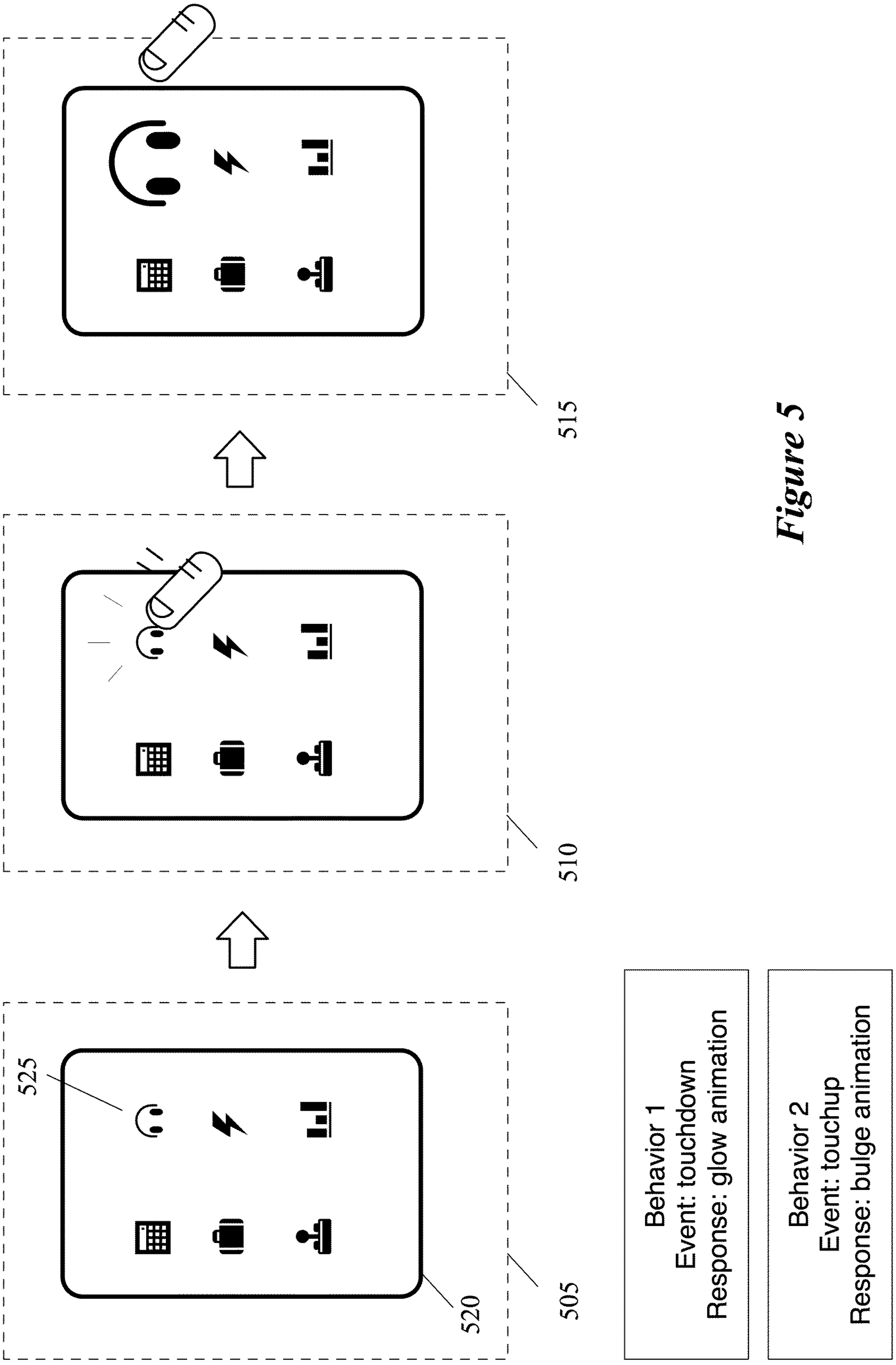

400
Start
405
Receive event
410
Find entity(entities)
415
Find behavior(s)
420
Identify response(s)
425
Execute response(s)
End

*Figure 4*



Behavior 1
Event: touchdown
Response: glow animation

Behavior 2
Event: touchup
Response: bulge animation

*Figure 5*

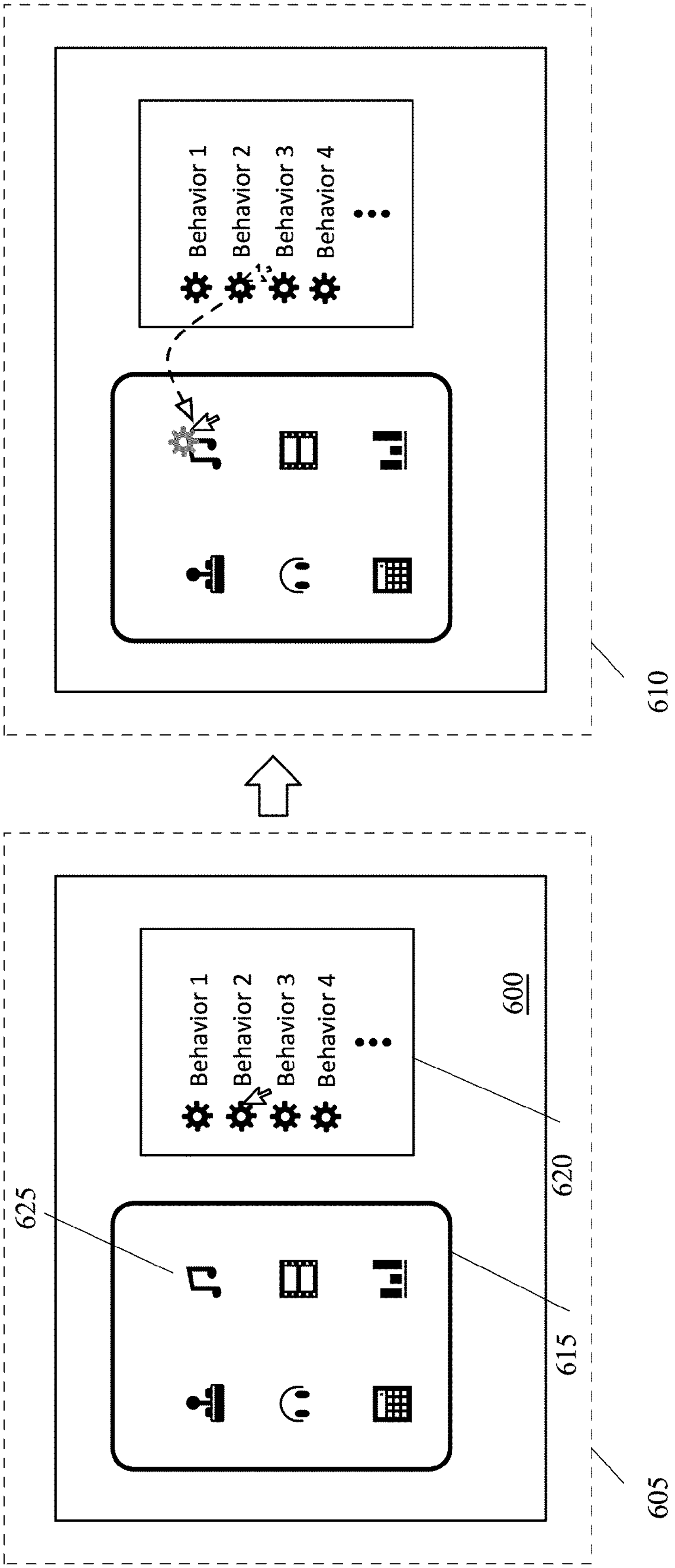
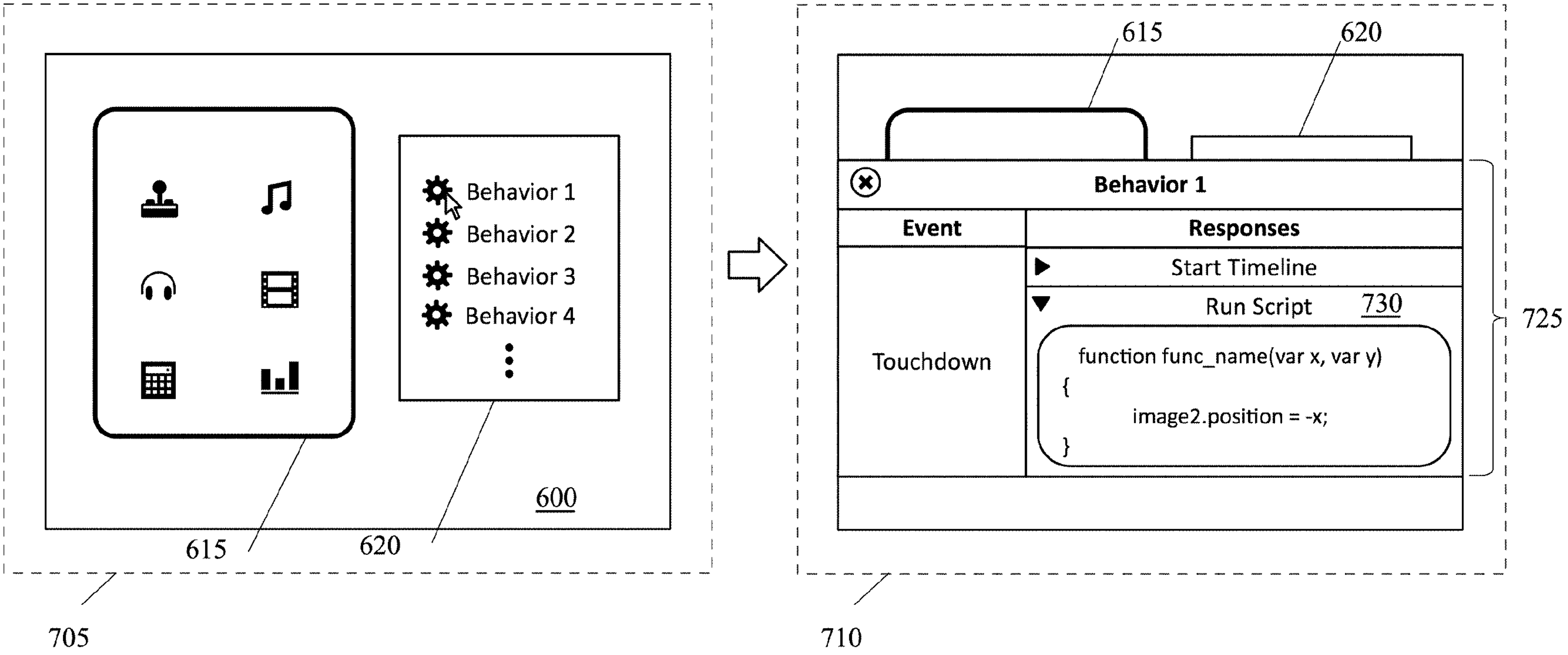

Behavior 1
Behavior 2
Behavior 3
Behavior 4
610
Behavior 1
Behavior 2
Behavior 3
Behavior 4
600
625
620
615
605

*Figure 6*



```
function func_name(var x, var y)
{
        image2.position = -x;
}
```

*Figure 7*

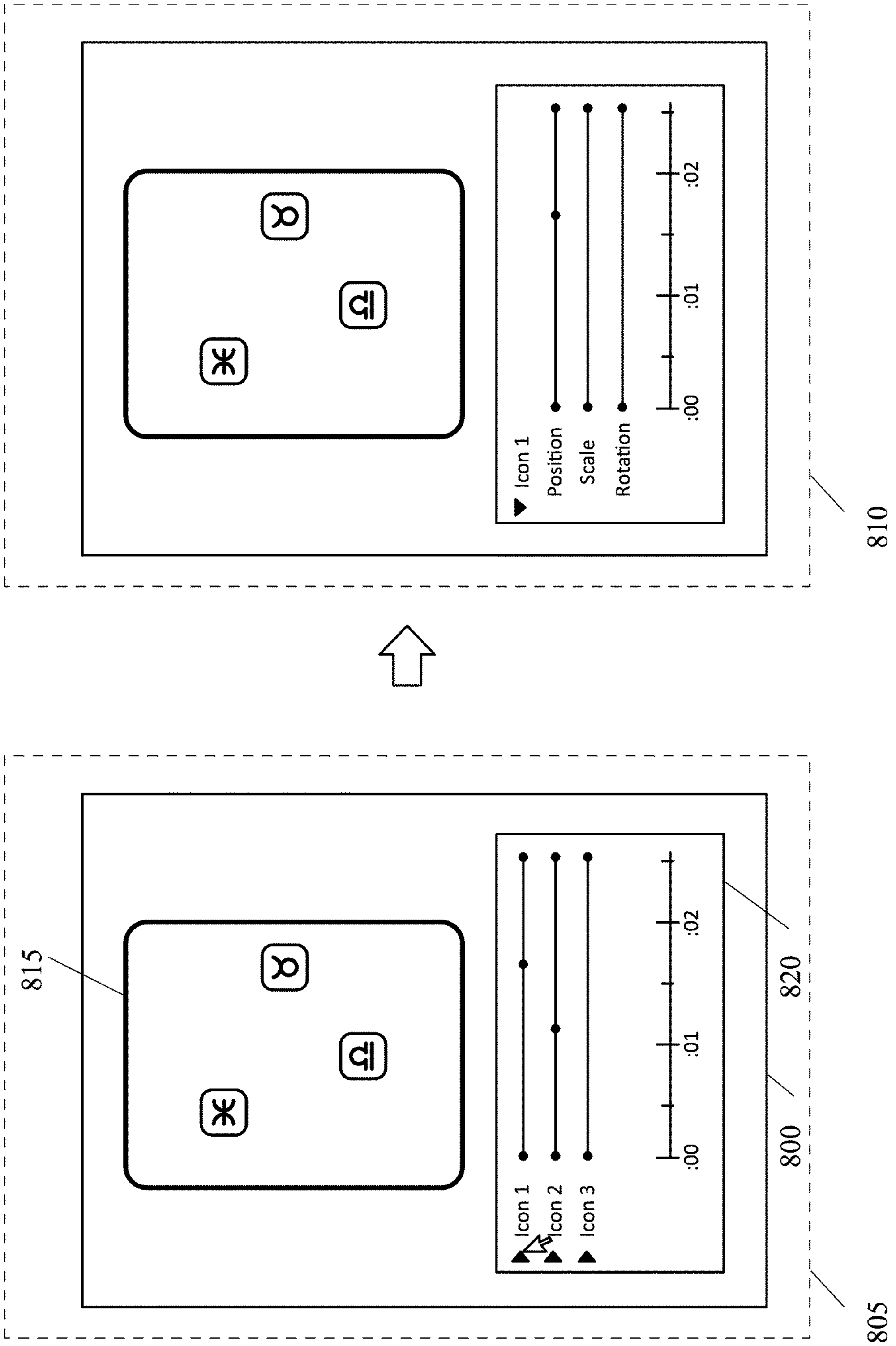

810
Icon 1
Position
Scale
Rotation
:00
:01
:02
815
820
800
805
Icon 1
Icon 2
Icon 3
:00
:01
:02

*Figure 8*

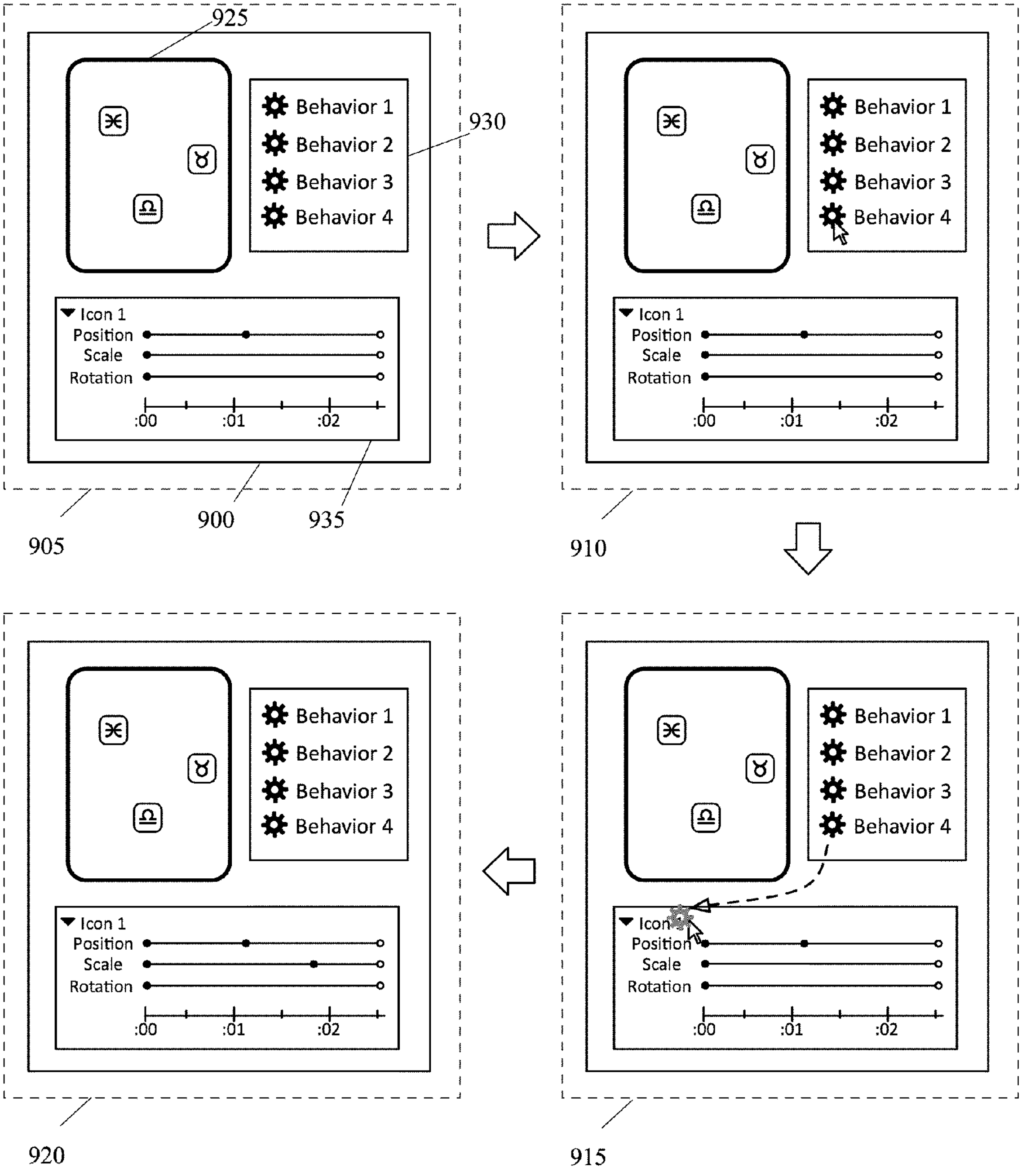

925
930
Behavior 1
Behavior 2
Behavior 3
Behavior 4
Icon 1
Position
Scale
Rotation
:00
:01
:02
900
935
905
910
915
920

*Figure 9*

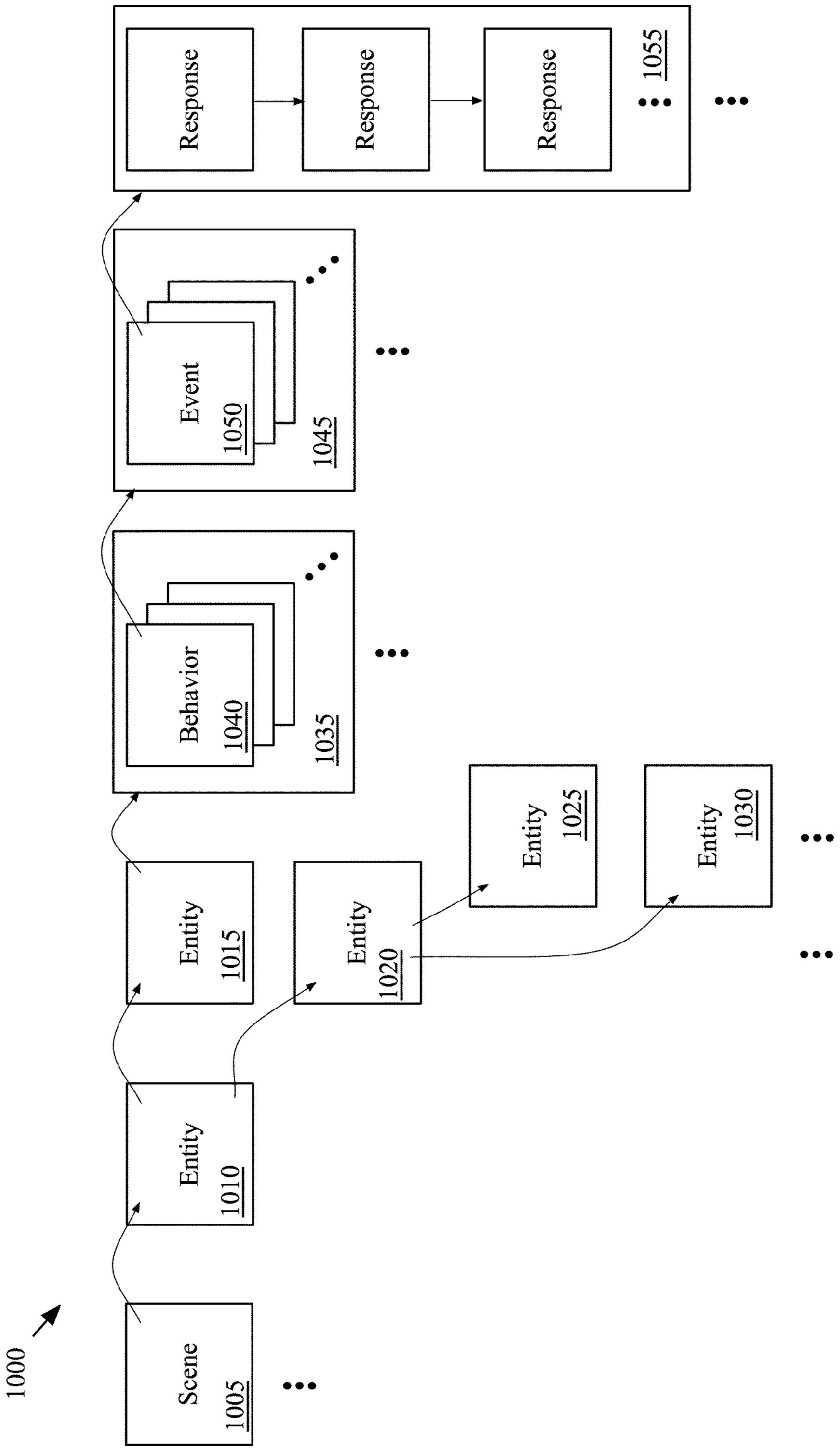

1000
Scene
1005
Entity
1010
Entity
1015
Entity
1020
Entity
1025
Entity
1030
Behavior
1040
1035
Event
1050
1045
Response
Response
Response
1055

*Figure 10*

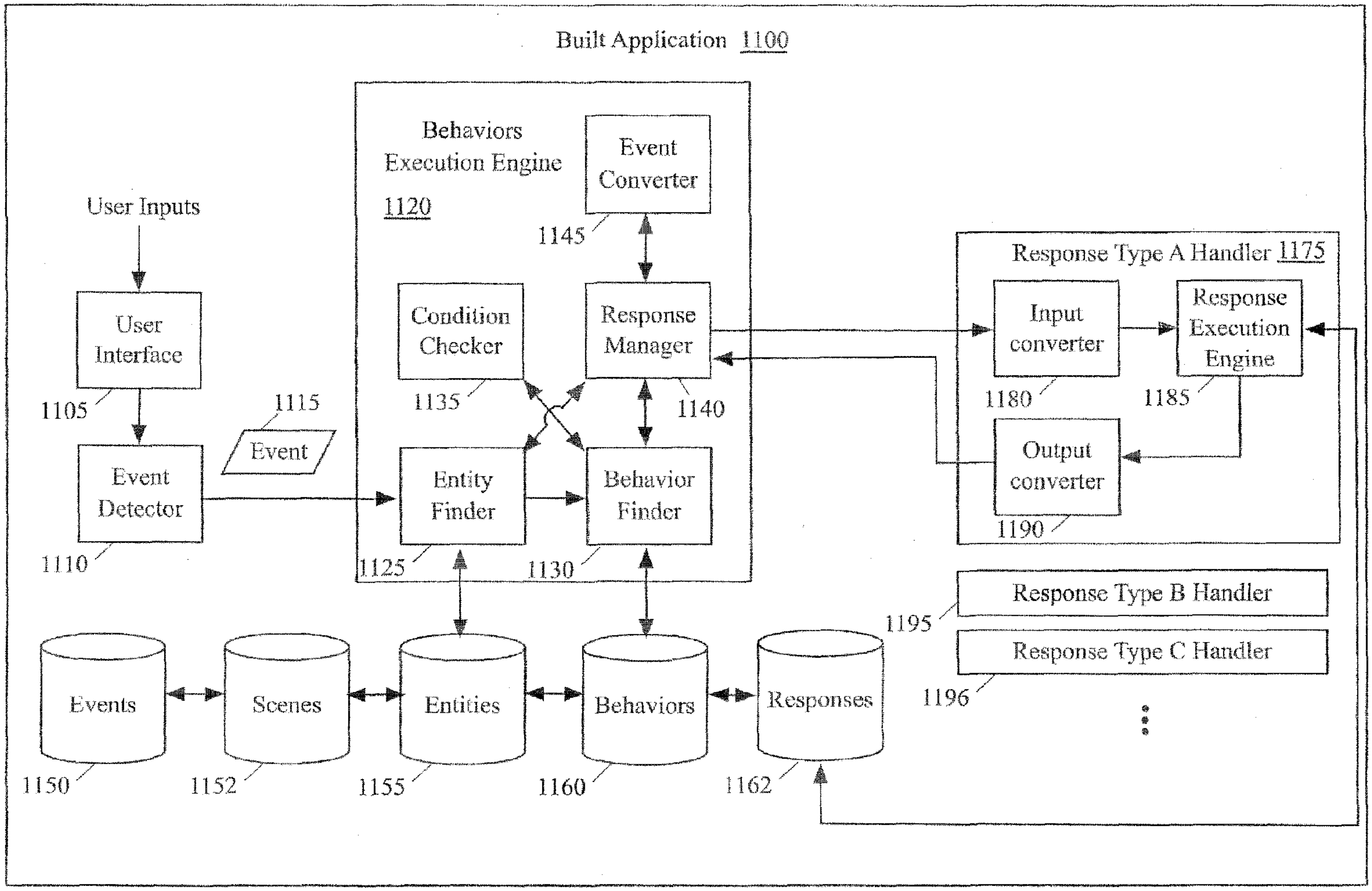

Built Application 1100
Behaviors Execution Engine 1120
Event Converter
1145
User Inputs
User Interface
1105
Condition Checker
1135
Response Manager
1140
Response Type A Handler 1175
Input converter
1180
Response Execution Engine
1185
Output converter
1190
1115
Event
Event Detector
1110
Entity Finder
1125
Behavior Finder
1130
Response Type B Handler
1195
Response Type C Handler
1196
Events
1150
Scenes
1152
Entities
1155
Behaviors
1160
Responses
1162

*Figure 11*

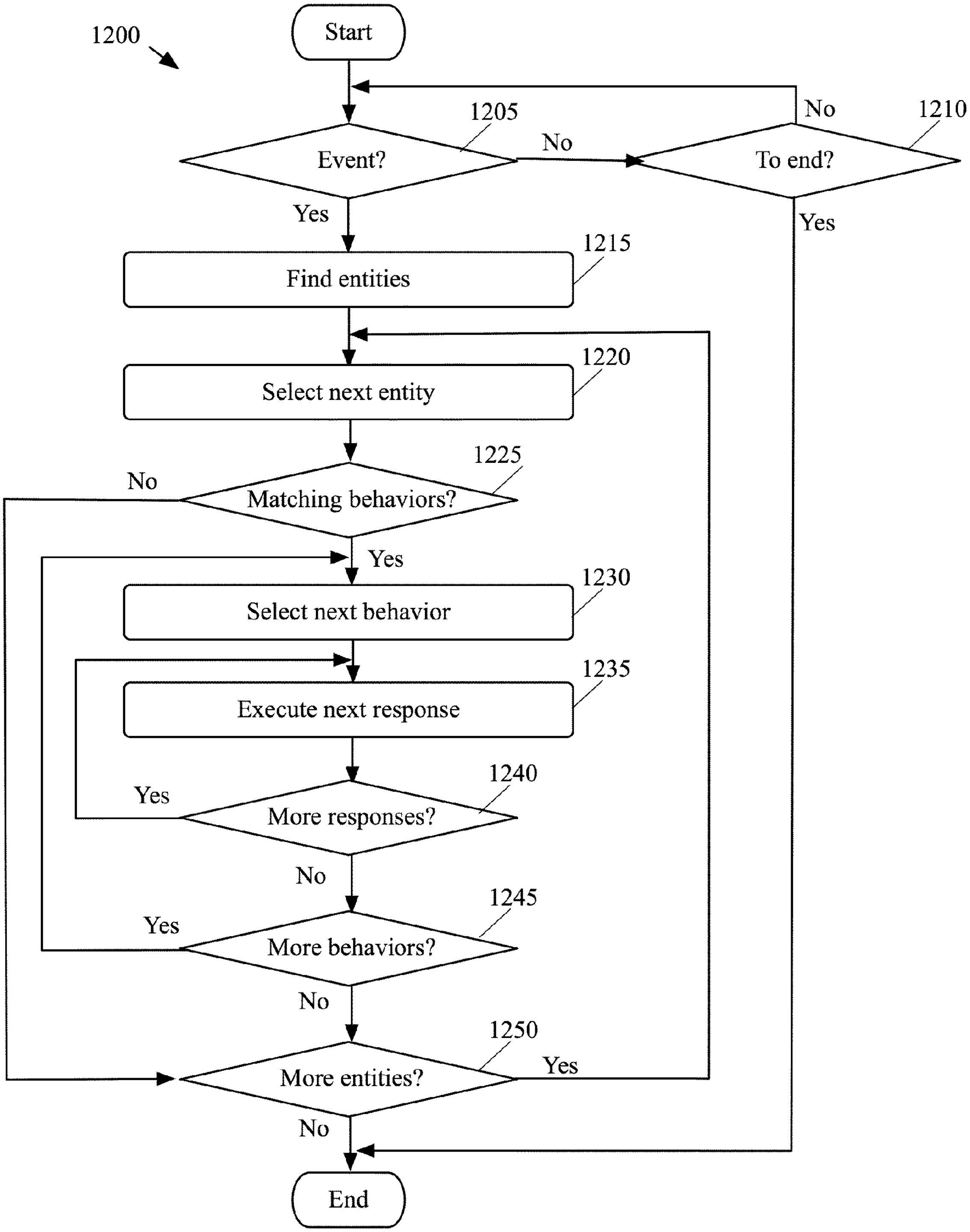

1200
Start
1205
Event?
No
1210
To end?
No
Yes
Yes
1215
Find entities
1220
Select next entity
1225
Matching behaviors?
No
Yes
1230
Select next behavior
1235
Execute next response
1240
More responses?
Yes
No
1245
More behaviors?
Yes
No
1250
More entities?
Yes
No
End

*Figure 12*

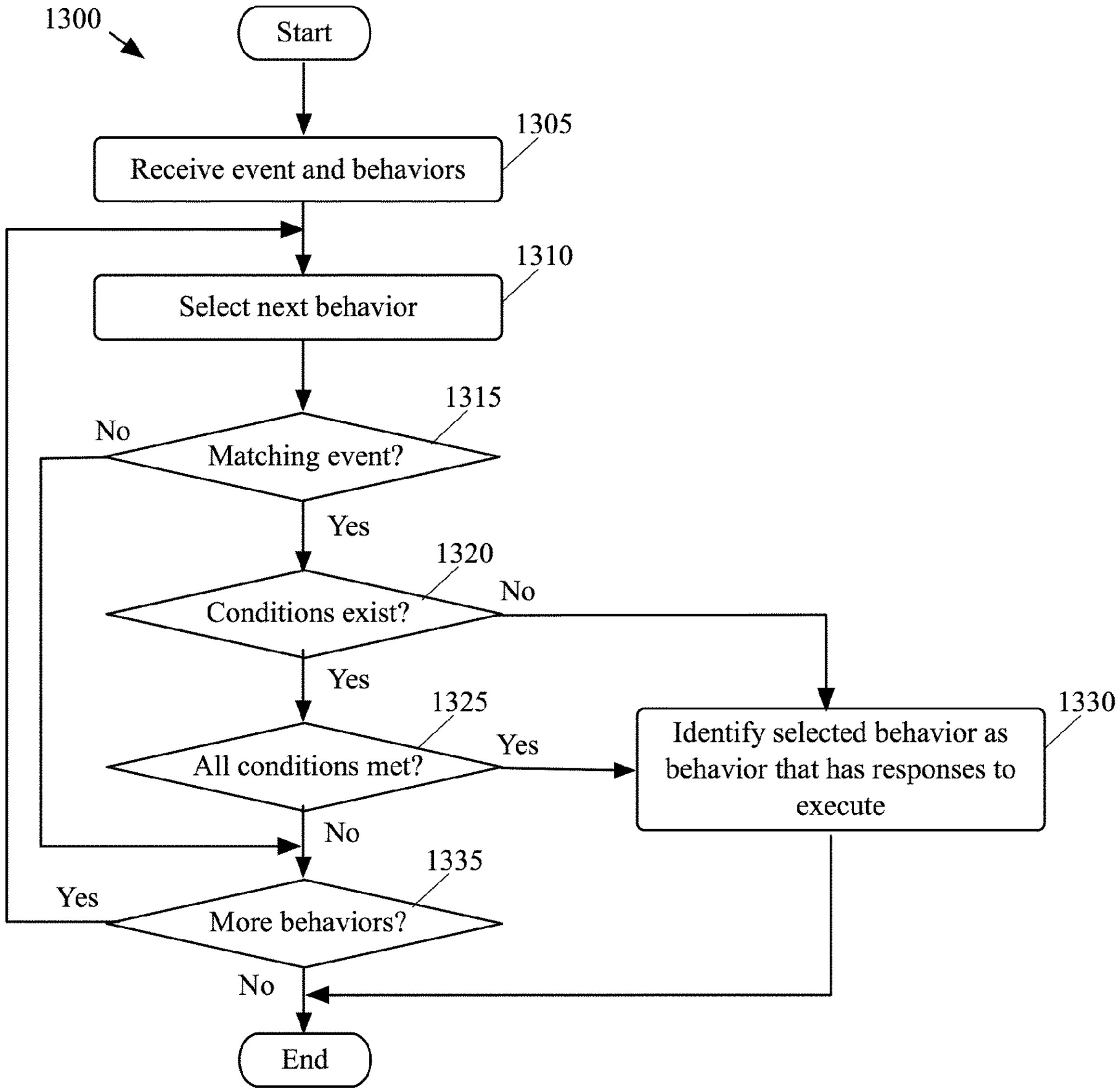
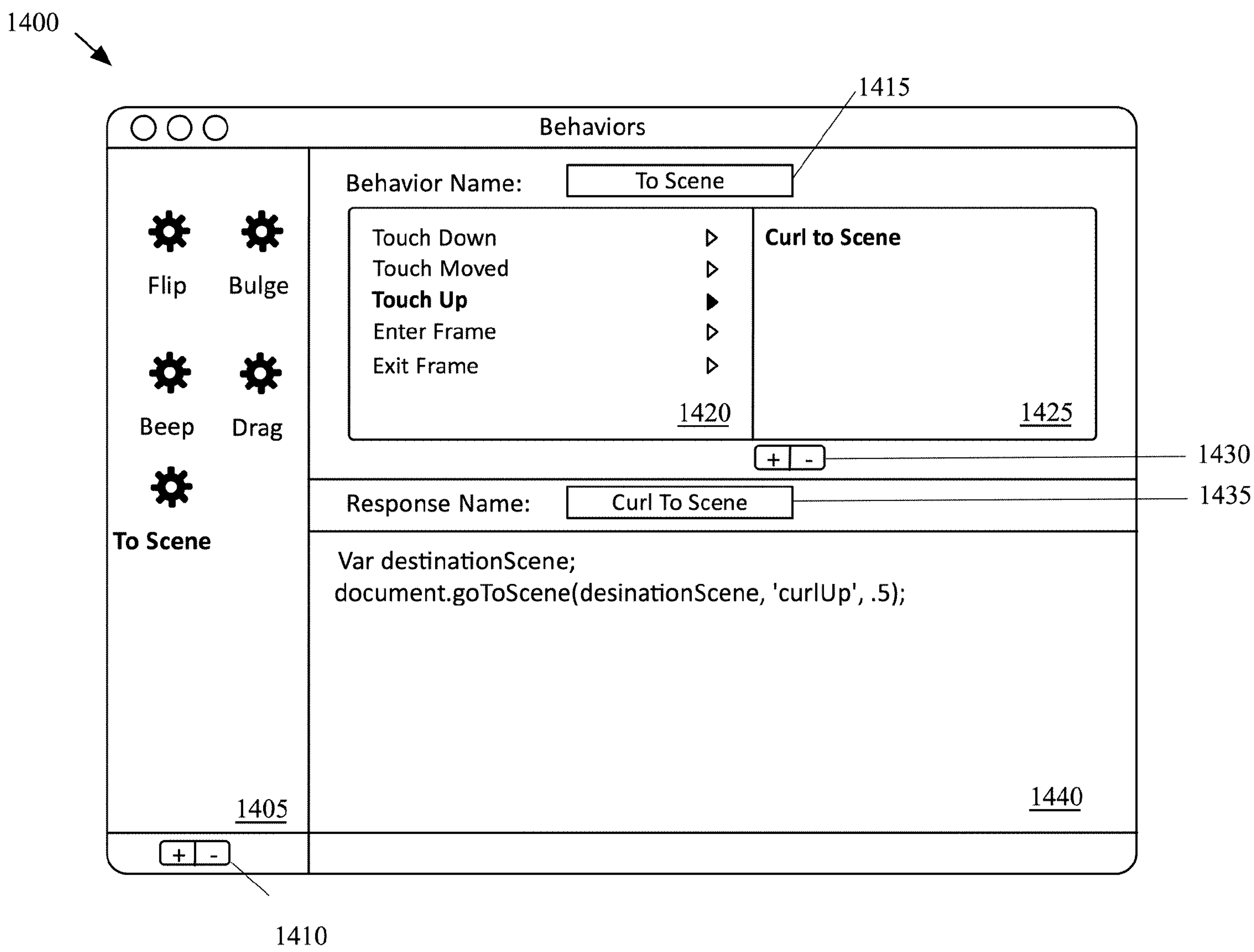

1300
Start
1305
Receive event and behaviors
1310
Select next behavior
1315
Matching event?
No
Yes
1320
Conditions exist?
No
Yes
1325
All conditions met?
Yes
1330
Identify selected behavior as behavior that has responses to execute
No
1335
More behaviors?
Yes
No
End

Figure 13



Behavior Name: To Scene

Response Name: Curl To Scene

```
Var destinationScene;
document.goToScene(desinationScene, 'curlUp', .5);
```

*Figure 14*

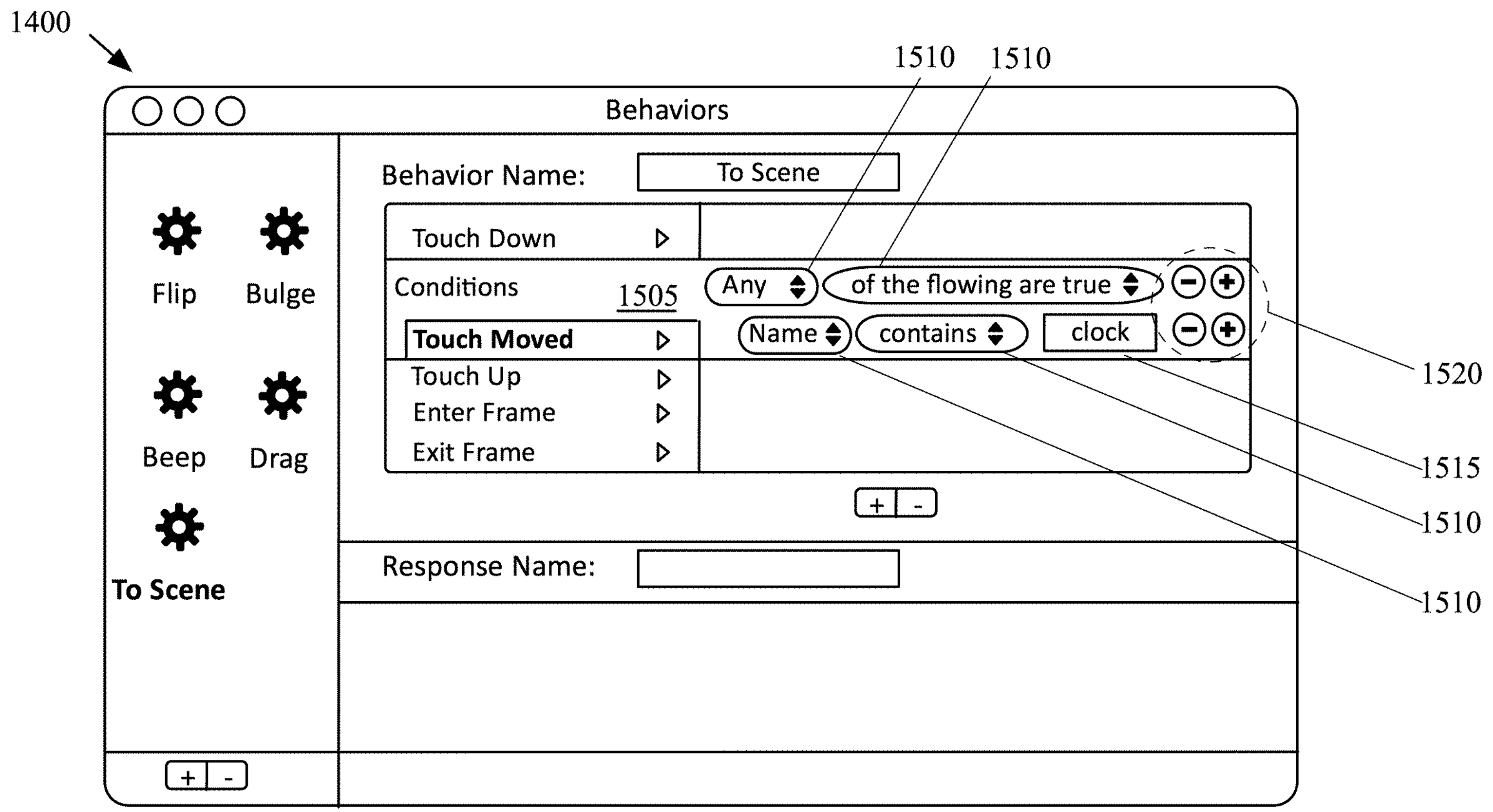

1400
Behaviors
Flip
Bulge
Beep
Drag
To Scene
+ -
Behavior Name:
To Scene
Touch Down
Conditions
1505
Touch Moved
Touch Up
Enter Frame
Exit Frame
Any
of the flowing are true
Name
contains
clock
+ -
Response Name:
1510
1510
1520
1515
1510
1510

*Figure 15*

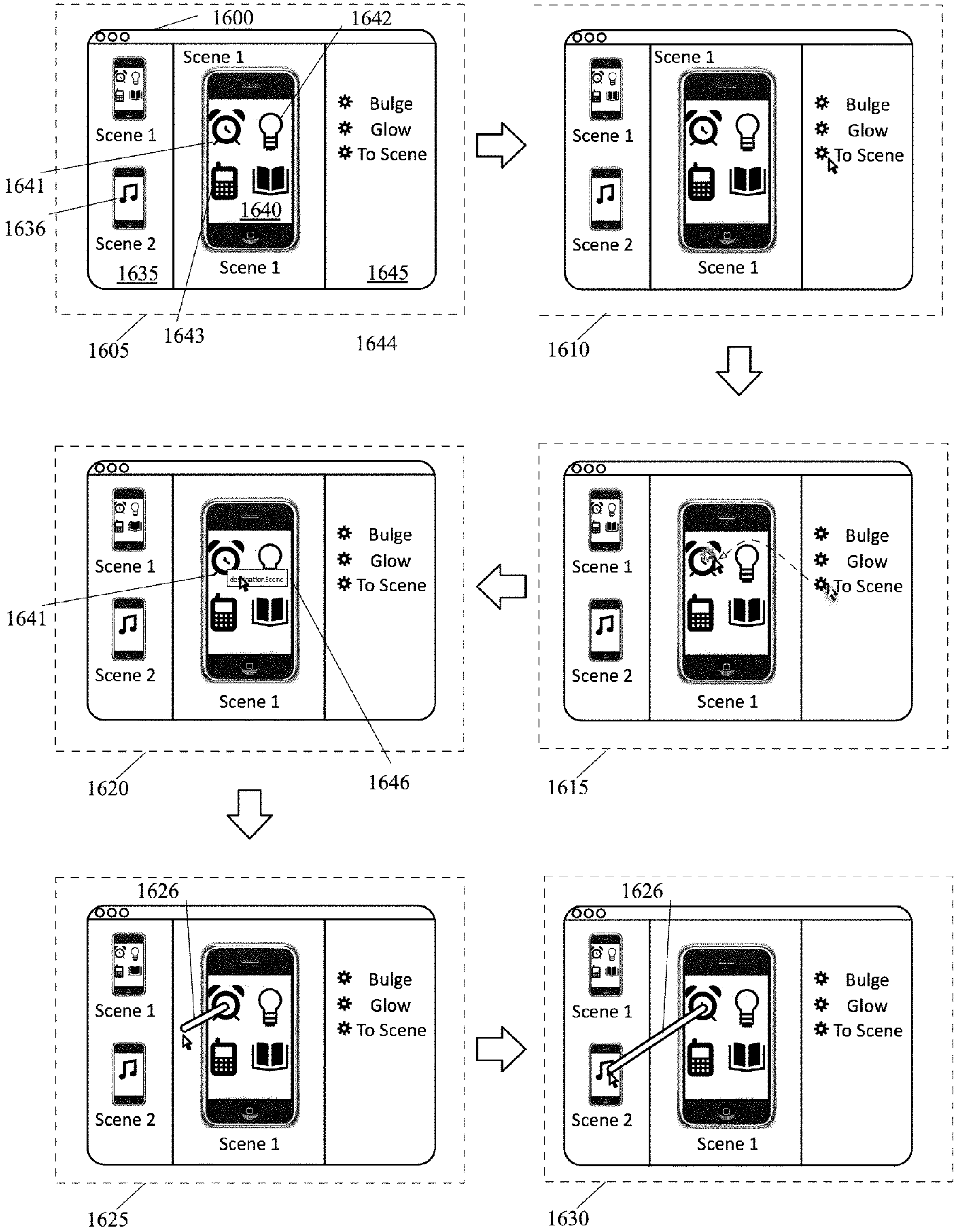

1600
1642
Scene 1
Bulge
Glow
To Scene
1641
1636
1640
Scene 2
1635
1645
1605
1643
1644
1610
1620
1646
1615
1626
1625
1630

*Figure 16*

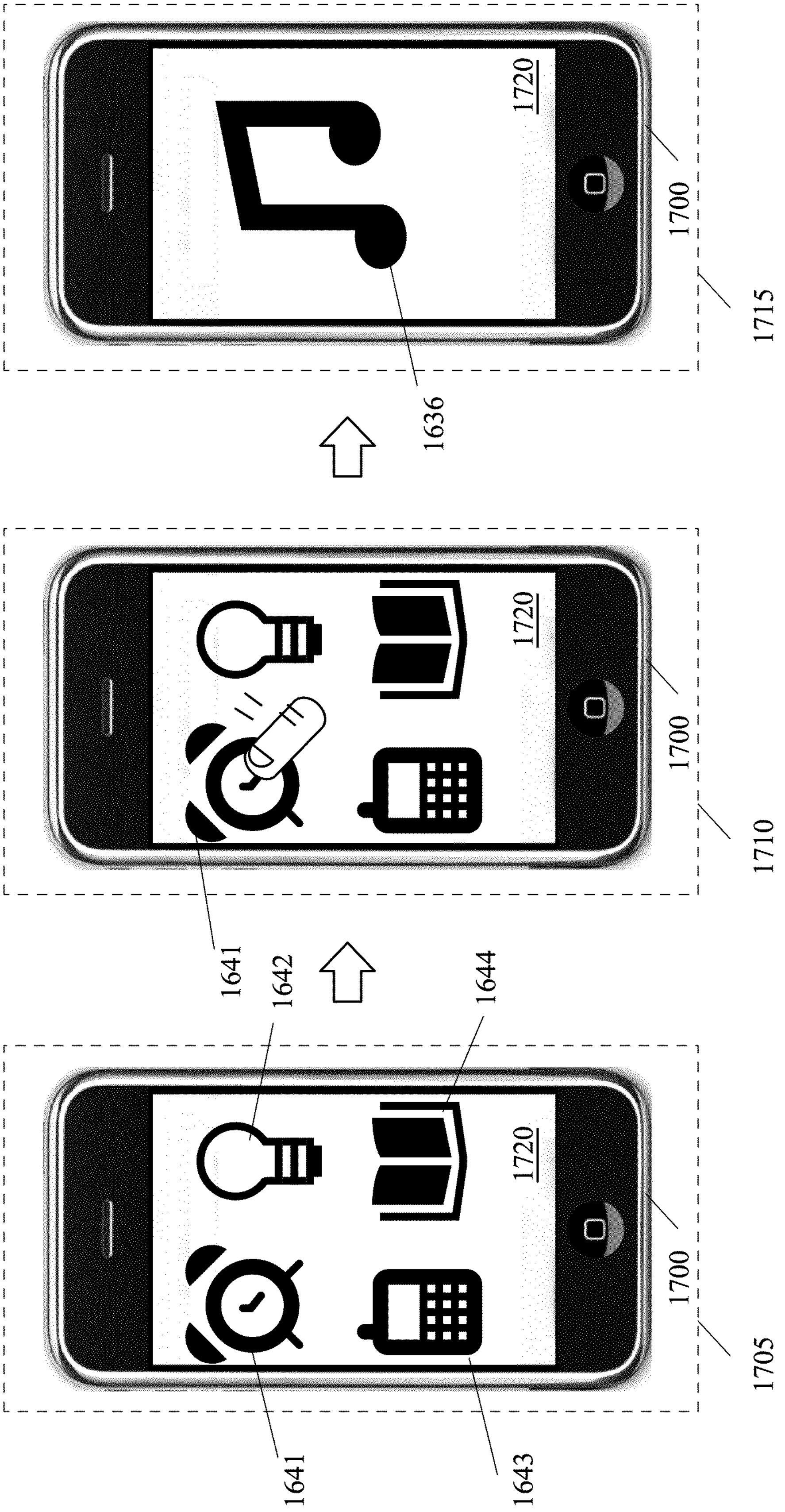

1720
1700
1715
1636
1720
1700
1710
1641
1642
1644
1720
1700
1705
1641
1643

*Figure 17*

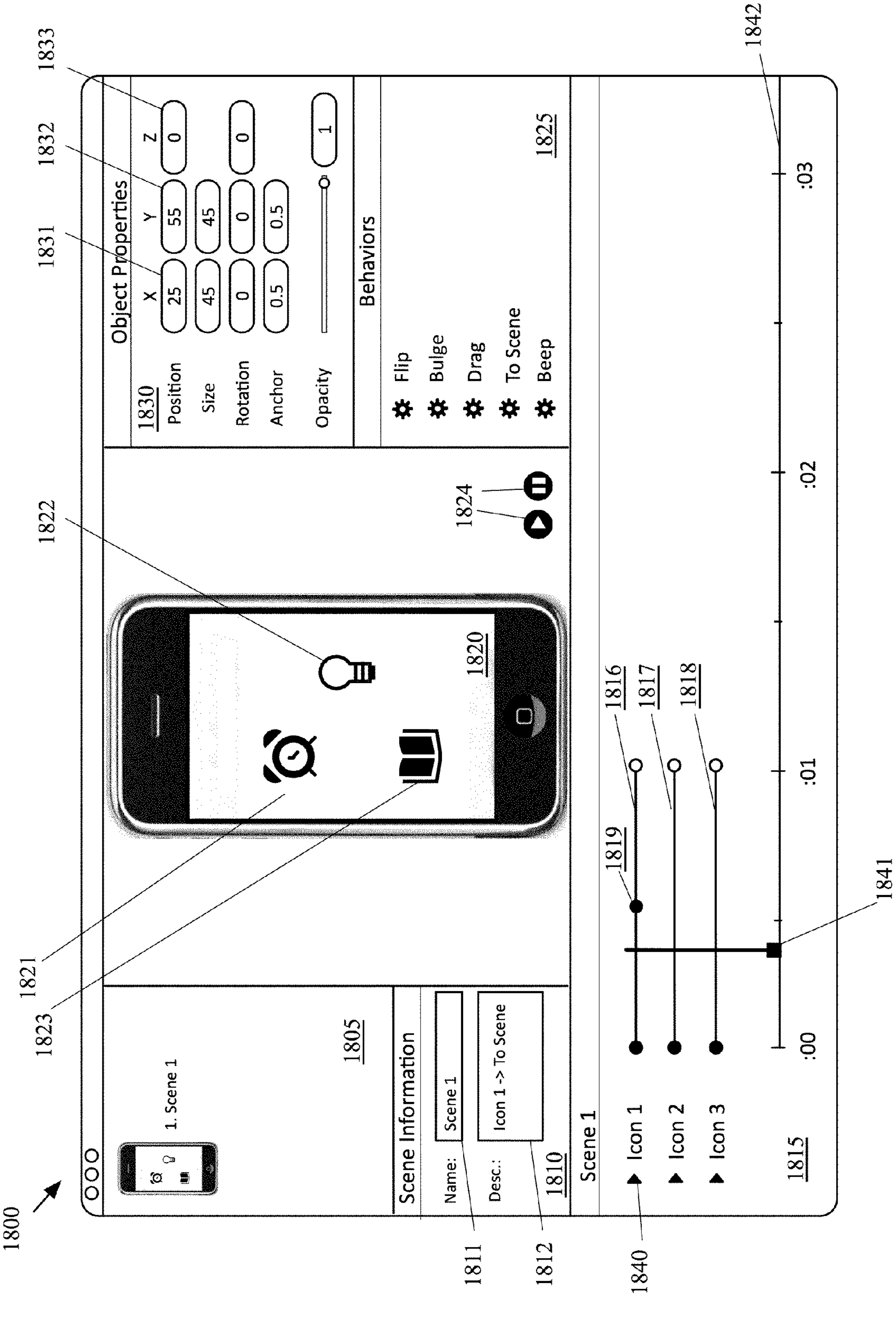
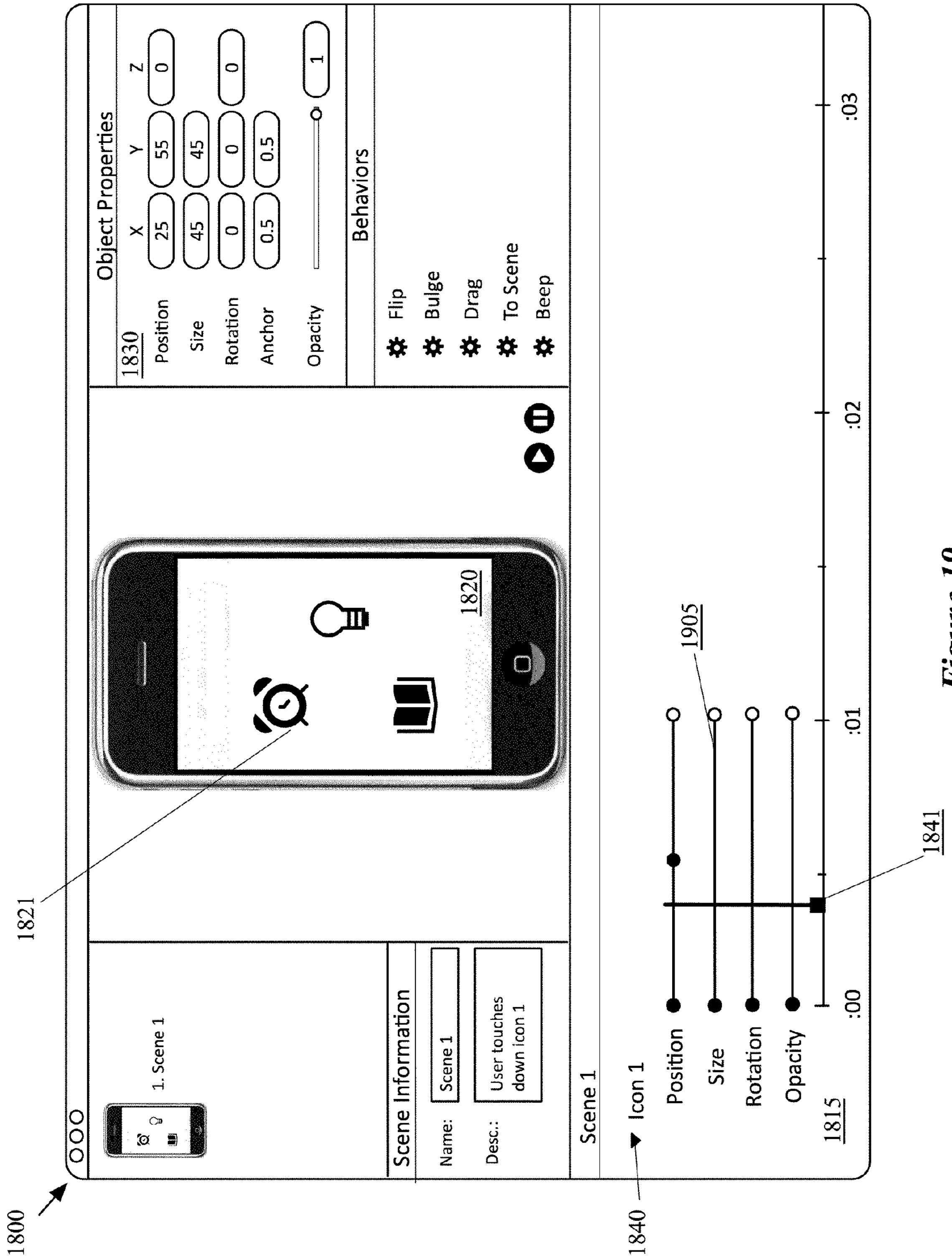

1800
1805
1. Scene 1
Scene Information
1810
Name:
Scene 1
Desc.:
Icon 1 -> To Scene
1811
1812
1815
Scene 1
Icon 1
Icon 2
Icon 3
1840
:00
:01
:02
:03
1841
1842
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
Object Properties
1830
X
Y
Z
Position
25
55
0
Size
45
45
Rotation
0
0
0
Anchor
0.5
0.5
Opacity
1
1831
1832
1833
Behaviors
Flip
Bulge
Drag
To Scene
Beep

*Figure 18*



1. Scene 1

Scene Information

Name: Scene 1

Desc.: User touches down icon 1

Object Properties

| 1830 | X | Y | Z |
|---|---|---|---|
| Position | 25 | 55 | 0 |
| Size | 45 | 45 | |
| Rotation | 0 | 0 | 0 |
| Anchor | 0.5 | 0.5 | |
| Opacity | | | 1 |

Behaviors

- Flip
- Bulge
- Drag
- To Scene
- Beep

Scene 1

▼ Icon 1

*Figure 19*

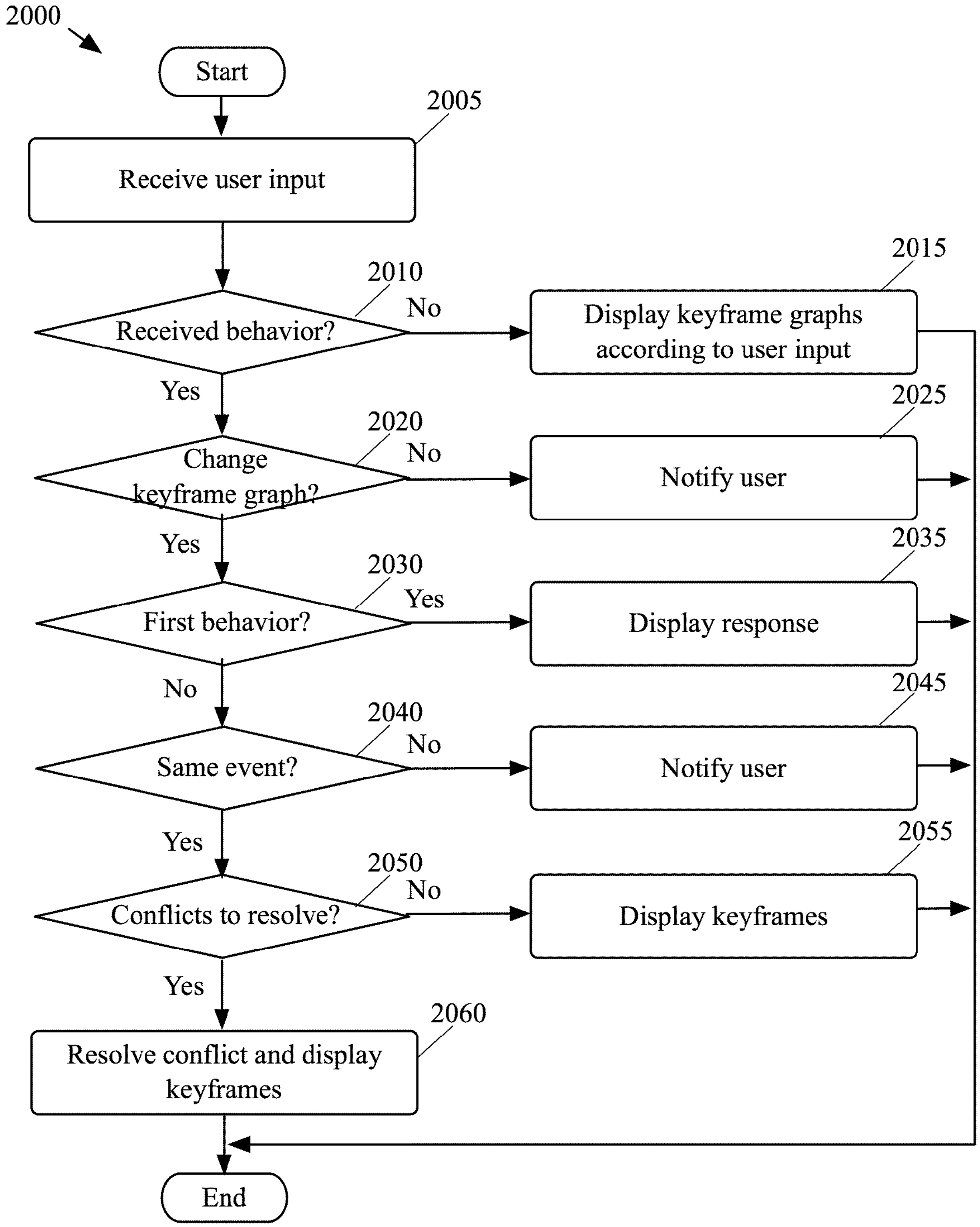

2000
Start
2005
Receive user input
2010
Received behavior?
No
2015
Display keyframe graphs according to user input
Yes
2020
Change keyframe graph?
No
2025
Notify user
Yes
2030
First behavior?
Yes
2035
Display response
No
2040
Same event?
No
2045
Notify user
Yes
2050
Conflicts to resolve?
No
2055
Display keyframes
Yes
2060
Resolve conflict and display keyframes
End

*Figure 20*

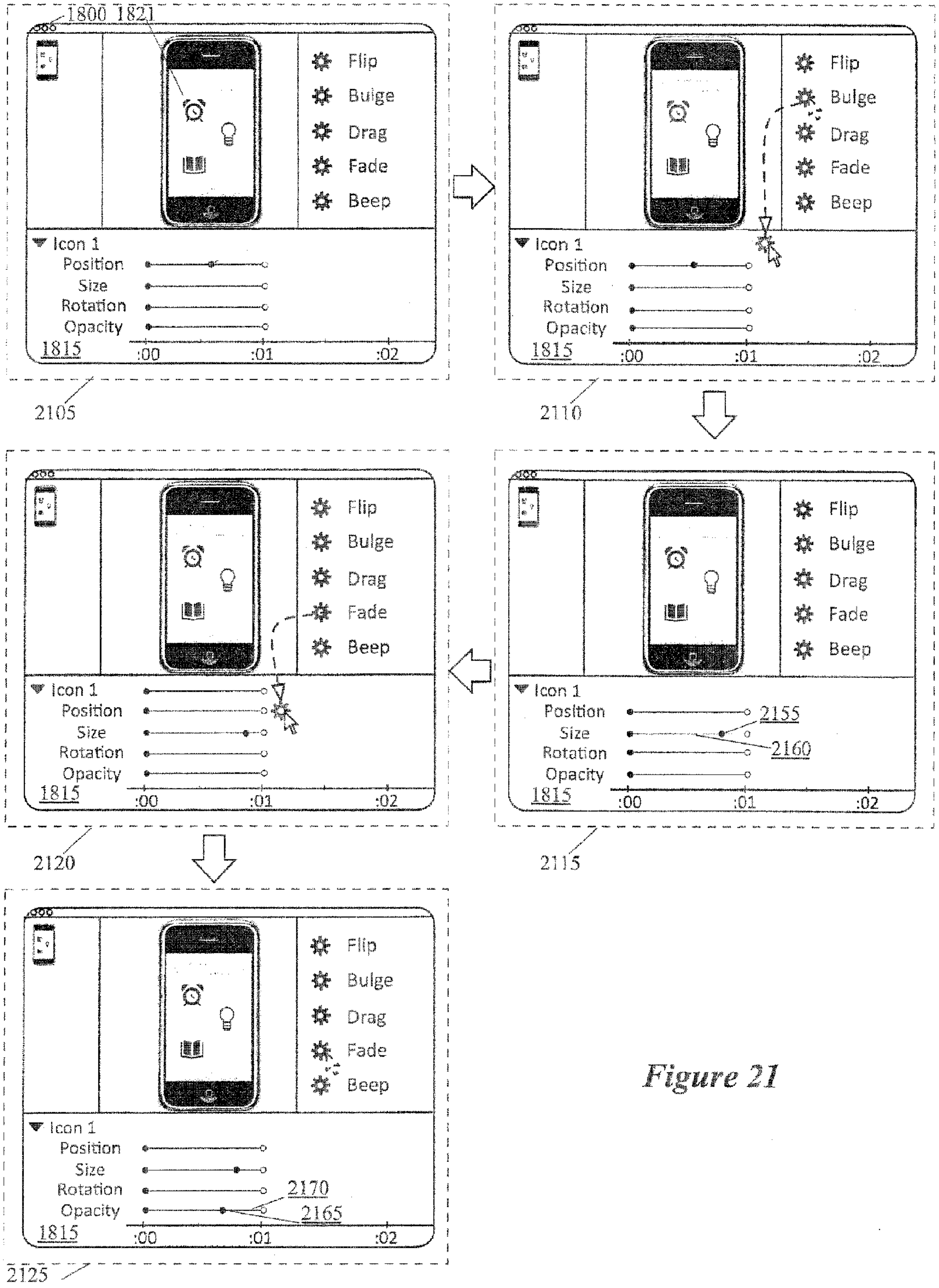

1800
1821
Flip
Bulge
Drag
Fade
Beep
Icon 1
Position
Size
Rotation
Opacity
1815
:00
:01
:02
2105
Flip
Bulge
Drag
Fade
Beep
Icon 1
Position
Size
Rotation
Opacity
1815
:00
:01
:02
2110
Flip
Bulge
Drag
Fade
Beep
Icon 1
Position
Size
Rotation
Opacity
1815
:00
:01
:02
2120
Flip
Bulge
Drag
Fade
Beep
Icon 1
Position
2155
Size
Rotation
2160
Opacity
1815
:00
:01
:02
2115
Flip
Bulge
Drag
Fade
Beep
Icon 1
Position
Size
Rotation
2170
Opacity
2165
1815
:00
:01
:02
2125

*Figure 21*

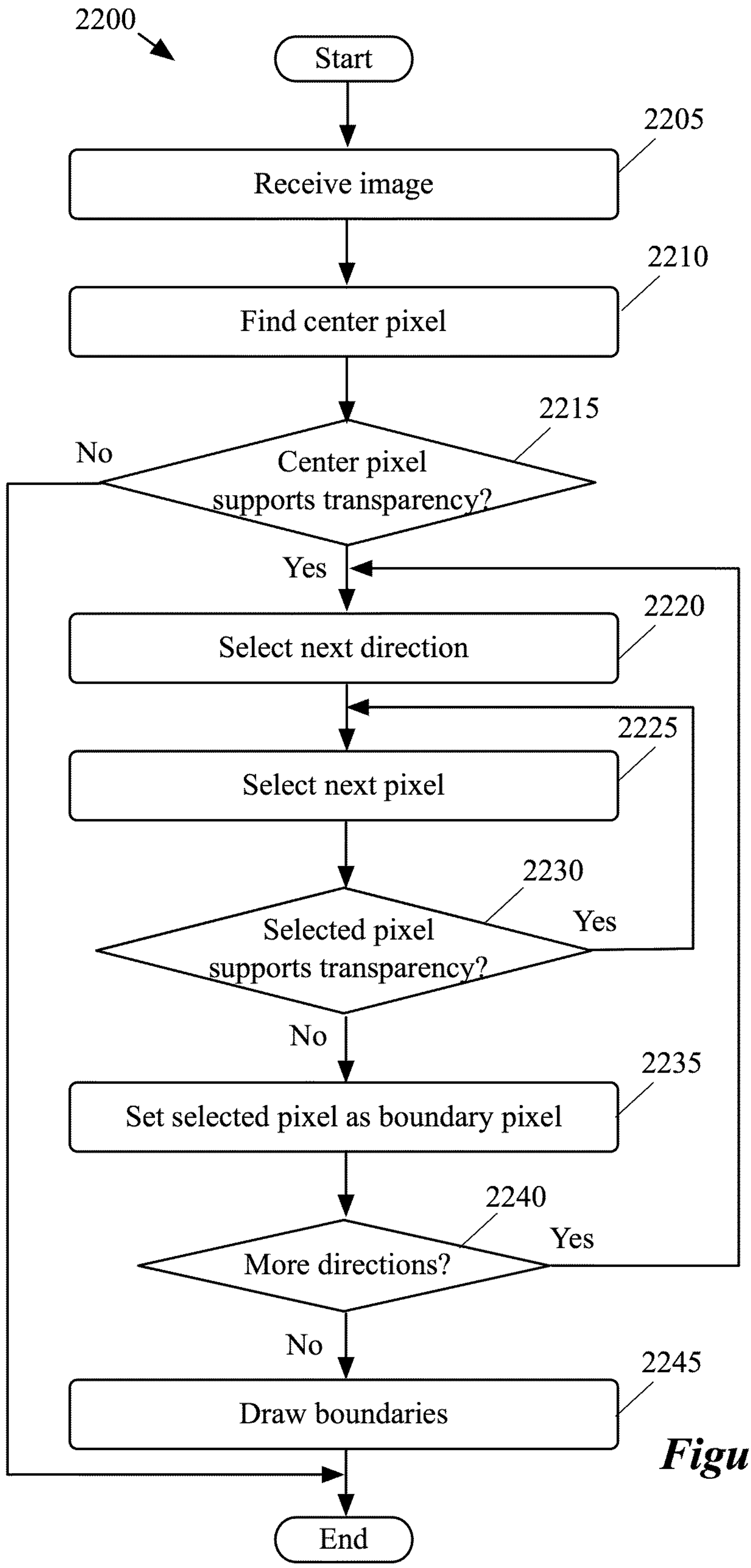

2200
Start
2205
Receive image
2210
Find center pixel
2215
Center pixel supports transparency?
No
Yes
2220
Select next direction
2225
Select next pixel
2230
Selected pixel supports transparency?
Yes
No
2235
Set selected pixel as boundary pixel
2240
More directions?
Yes
No
2245
Draw boundaries
End

*Figure 22*

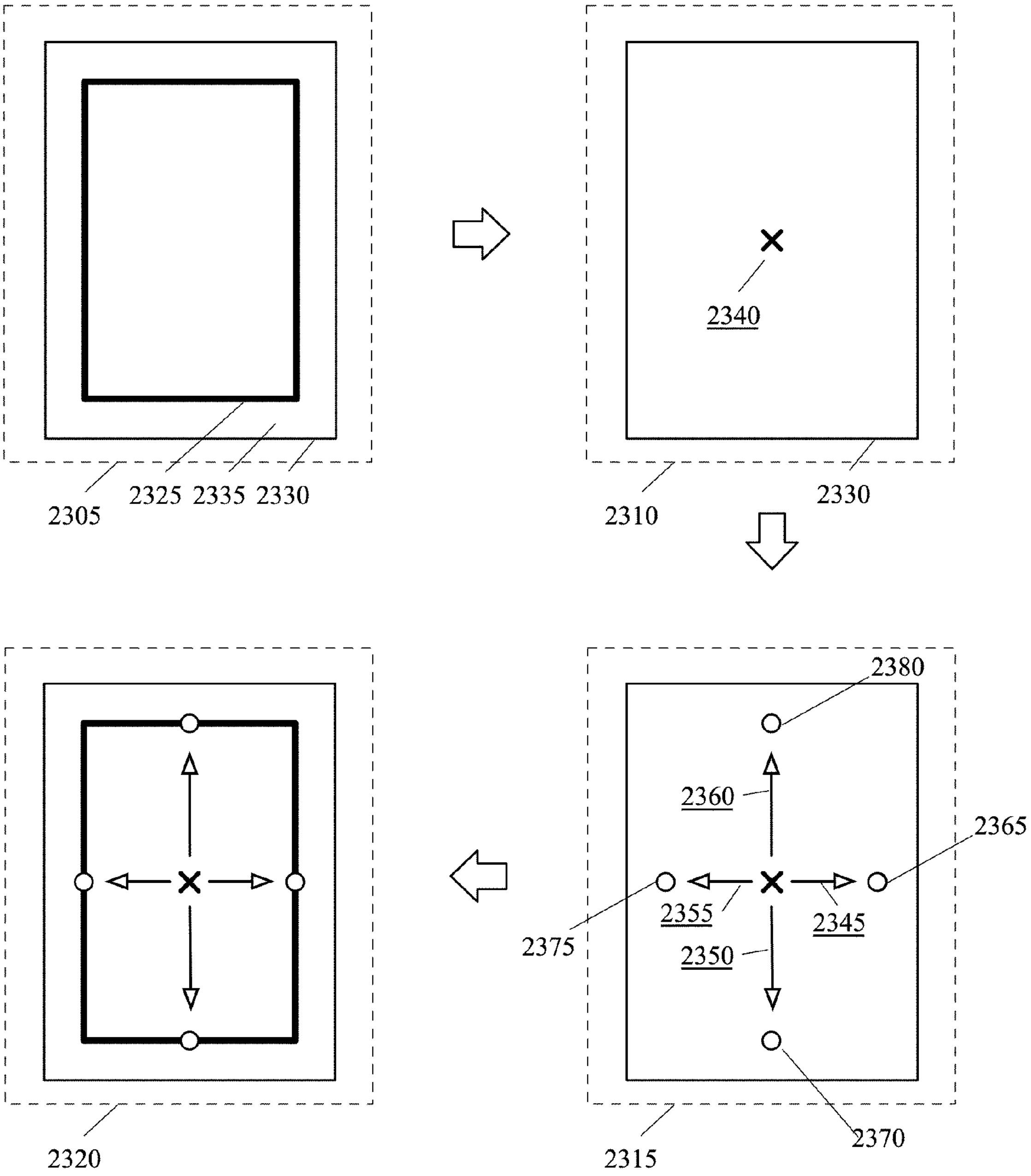

2340
2305
2325
2335
2330
2310
2330
2380
2360
2365
2355
2345
2375
2350
2320
2315
2370

*Figure 23*

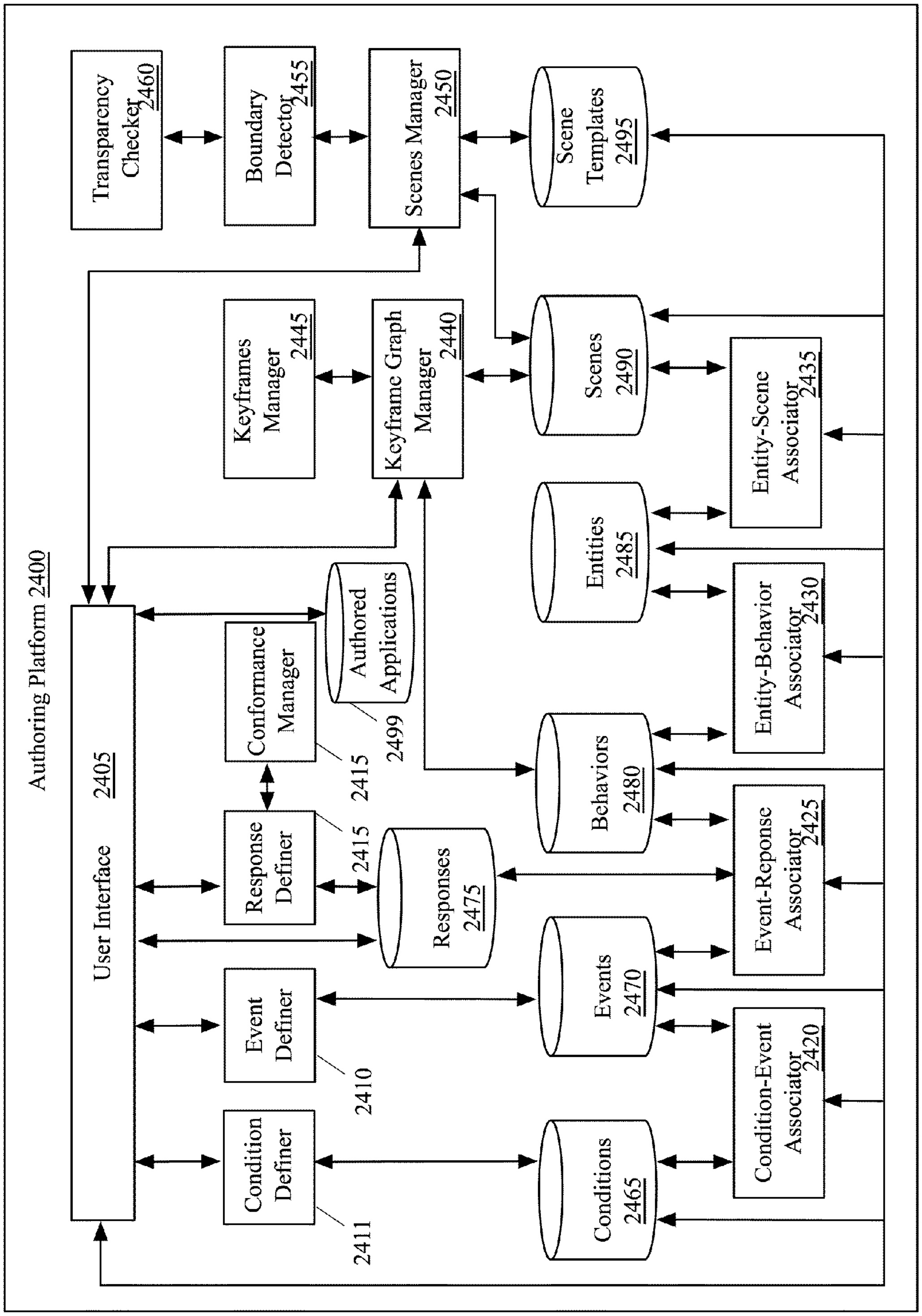

Authoring Platform 2400
User Interface 2405
Condition Definer
2411
Event Definer
2410
Response Definer
2415
Conformance Manager
2415
Authored Applications
2499
Keyframes Manager 2445
Keyframe Graph Manager 2440
Transparency Checker 2460
Boundary Detector 2455
Scenes Manager 2450
Scene Templates 2495
Scenes 2490
Entities 2485
Behaviors 2480
Responses 2475
Events 2470
Conditions 2465
Entity-Scene Associator 2435
Entity-Behavior Associator 2430
Event-Reponse Associator 2425
Condition-Event Associator 2420

*Figure 24*

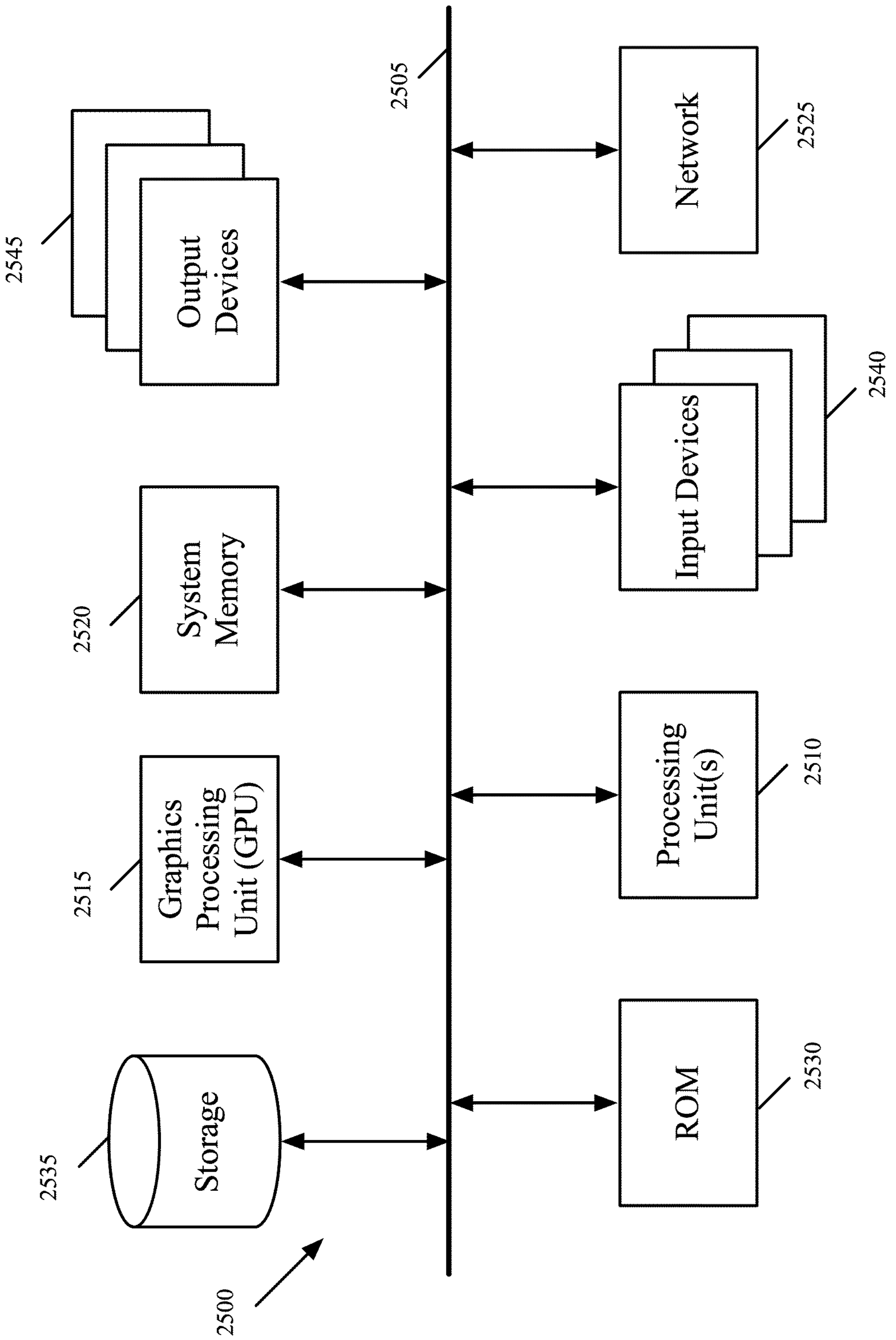

2500
2505
Storage
2535
Graphics Processing Unit (GPU)
2515
System Memory
2520
Output Devices
2545
ROM
2530
Processing Unit(s)
2510
Input Devices
2540
Network
2525

*Figure 25*

# CONFORMANCE PROTOCOL FOR HETEROGENEOUS ABSTRACTIONS FOR DEFINING USER INTERFACE BEHAVIORS

## BACKGROUND

Designing and developing software applications for running on computing devices is a daunting task, as it requires special knowledge and skill as well as experience. Everyday users of computing devices who have the desire and creativity to build their own applications are often driven off by complex and incomprehensible coding syntaxes and unfamiliar concepts like compiling and debugging. For this reason, most people opt to purchase software applications written by professional developers and run the applications on the computing devices they own. Several application-building applications have been developed to lower the barrier to writing software applications. However, these application-building applications still bear difficulties to overcome by everyday people.

## BRIEF SUMMARY

Some embodiments of the invention provide an authoring platform for authoring software applications by defining user interface (UI) behaviors, which are associations of one or more events with one or more responses. In some embodiments, an event is a user input that an authored application receives from a user of that authored application while the application is being executed. For instance, a user's clicking on a graphical item (e.g., an icon) of the application is an event that the application receives from the user. An event can also be programmatic. For instance, when a soccer game application is being executed, a graphical object representing a soccer ball colliding with another graphical object representing the goal may be programmatically defined as an event. A response is an action that the application performs in response to the received event. For instance, upon receiving the user's click on an icon, the application may enlarge the icon. Also, the soccer game application may increment the value for the score in response to an occurrence of the goal-scoring event (i.e., the soccer ball hitting the goal).

In some embodiments, an application built by the authoring platform of some embodiments includes one or more scenes. A scene in some embodiments is an interactive "page" of the application. The application can switch from one scene to another based on the user's interaction with the scene. Each scene in some embodiments includes one or more entities with which a user of the application can interact. Entities are graphical objects displayed on a display of a machine on which the application executes. For instance, entities may be graphical icons on which the user can click. The application displays the scenes in a certain order and each scene may have a different set of entities.

The authoring platform of some embodiments allows a user of the authoring platform to define events and responses and to associate the events and responses as behaviors. The authoring platform of some embodiments also allows the user of the authoring platform to associate a behavior with an entity of a scene of the authored application. The authored application performs the response associated with the event of the behavior when the event occurs on the entity while the authored application executes on a machine. For instance, the user of the authoring application defines a response that enlarges an entity. The user also defines an event that represents touching an entity with a finger of a user of an authored application. The user associates the defined response with the defined event and then defines the association of the event and response as a behavior. The user associates this behavior with an entity of a scene of an interactive application that the user is building using the authoring platform. When the user of the application touches the entity with her finger, the application performs the response by displaying the enlarged entity.

As mentioned above, the authoring platform of some embodiments allows the user of the authoring platform to associate an entity with one or more behaviors. Each behavior can include one or more events. Each event in turn can be associated with one or more responses. That is, when an event occurs on an entity while an authored application executes, the application may perform one or more responses. In some cases, these responses may be in heterogeneous types.

The heterogeneous types of responses in some embodiments include a script response, an animation response, a complied code response, an audio response, etc. A script response is a script (e.g., JavaScript) that the authored application would perform in response to receiving an event that is associated with the script response. An animation response is an animation that the authored application would perform in response to receiving an event that is associated with the animation response. For instance, the application would animate a graphical icon glow in response to user's clicking the icon or move the graphical icon from one location of a scene to another location of the scene. A compiled code response is an executable piece of program code that the authored application would invoke in response to receiving an event that is associated with the complied code response. For instance, the application would invoke a compiled C++ code to download a file from the Internet in response to receiving a click on a graphical icon. An audio response is an audio file that the authored application would playback in response to receiving an event that is associated with the audio response.

The authoring platform of some embodiments provides a protocol to facilitate communications between heterogeneous types of responses while an authoring application that performs these responses executes. In particular, the authored application translates the input and output data of a response into parameters that conform to this protocol such that output data of one type of response can be used as the input data of another type of response. For instance, the authored application translates a new position in a scene, to which an animation response moves an icon, into parameters that conform to the protocol. The authored application translates the parameters to input variables for a script response so that the script response runs its script with the input variables.

The authoring platform of some embodiments provides a tool for defining and editing behaviors. The user of the authoring platform uses this tool to define events and responses and define behaviors by associating the events and responses. For instance, the authoring platform provides a graphical user interface (GUI) referred to as a behavior editor. The behavior editor in some embodiments is for defining and editing a behavior. The behavior editor in some embodiments includes an events column, a responses column, and a script editing area. In the events column, the behavior editor lists events of the behavior that is being defined and/or edited by the behavior editor. The behavior editor lists responses. When the user of the authoring platform selects an event listed in the events column, the responses column lists the responses that are associated with the selected event. When the user of the authoring platform selects a script response listed in the responses column, the behavior editor displays the response's script content in the script editing area.

The authoring platform of some embodiments provides a tool for visually associating an entity of a scene and a behavior. For instance, the authoring platform provides a GUI that includes a scene preview area and a behaviors library. The scene preview area displays a scene of an application being built by the authoring platform. That is, scene preview area displays the entities of the scene. The behaviors library displays a list of behaviors that are represented as graphical objects. The tool in some embodiments allows the user of the authoring platform to select and drag a behavior from the behaviors library and to drop it onto an entity displayed in the scene preview area. In this manner, the user can associate an entity with a behavior visually.

The authoring platform of some embodiments provides a tool for visually combining several animation responses for an entity of a scene of an application being authored. For instance, the authoring platform provides a GUI that includes a key indices display area for displaying key-indexed graphs. A key-indexed graph in some embodiments is displayed as a line that horizontally expands the key indices display area. One end of the key-indexed graph represents the beginning of duration of the corresponding scene and the other end of the key-indexed graph represents the end of the duration. When the scene is played back, the scene will display its entities for the duration represented by the length of the key-indexed graph.

In some embodiments, the GUI allows the user of the authoring platform to place key indices (e.g., keyframes) on the key-indexed graph. A pair of key indices represents a start and an end of an animation for an entity of a scene. For instance, the first key index of a key index pair defines a first location of the entity within the scene at the beginning of a time period and the second key index of the key index pair may define a second location of the entity within the scene at the end of the time period. When the scene is played back for the time period represented by the two key indices of the pair, the entity moves from the first location at the beginning of the time period to the second location at the end of the time period. In some embodiments, the intermediate positions of the icon being moved during the time period are interpolated based on the first and the second positions. Thus, an animation response may be defined as a set of key indices placed along a key-indexed graph.

Using the combining tool, the user of the authoring platform can combine several animation responses in the key-indexed graphs when the responses are associated with the same event. As mentioned above, an animation response may be represented as a set of key indices for one or more entities of a scene. Combining several animation responses in the key-indexed graphs therefore means combining the key indices of different responses in some embodiments. The tool in some embodiments allows the user to combine responses in the key indices display area by selecting and dragging several behaviors from the behaviors library and dropping the selected behaviors on the key indices display area. Once the behaviors are dropped onto the key indices display area, the key indices of the animation responses of the behaviors appear on the key-indexed graphs.

Some embodiments provide a method for automatically detecting boundaries of a transparent area within an image, which serves as the scene preview area of the authoring platform. In some cases, the manufacturer of a device provides the user of the authoring platform with the image having a transparent area. This transparent area in the image serves as the scene preview area. That is, the entities of a scene will appear in the transparent area within the provided image. The user can tailor the scenes of the application being authored to the provided image so that the scenes are displayed correctly in the display area for the device.

However, a manufacturer may change the shape and/or size of the transparent area within the image before finalizing the design for their device or when a new version of the device is being developed. By allowing automatic detection of boundaries of the transparent area, the method of some embodiments allows the user of the authoring platform to avoid changing the scenes to keep up with the changes to the shape and/or size of the transparent area of the image. The method of some such embodiments first finds the center pixel of the image and determines whether the center pixel supports transparency. The method in some embodiments determines that the center point supports transparency when the center pixel has an alpha value that is below a certain threshold value that is less than 1.0. In these embodiments, a pixel having an alpha value that is less than the threshold value is qualified as transparent. When the center pixel is determined to be transparent, the method expands the boundaries of the transparent area from the center pixel until the boundaries hit pixels that do not have alpha values or that have alpha values greater than the threshold value. The method then uses the expanded boundaries over which to place the entities.

The preceding Summary is intended to serve as a brief introduction to some embodiments of the invention. It is not meant to be an introduction or overview of all inventive subject matter disclosed in this document. The Detailed Description that follows and the Drawings that are referred to in the Detailed Description will further describe the embodiments described in the Summary as well as other embodiments. Accordingly, to understand all the embodiments described by this document, a full review of the Summary, Detailed Description and the Drawings is needed. Moreover, the claimed subject matters are not to be limited by the illustrative details in the Summary, Detailed Description and the Drawing, but rather are to be defined by the appended claims, because the claimed subject matters can be embodied in other specific forms without departing from the spirit of the subject matters.

## BRIEF DESCRIPTION OF THE DRAWINGS

The novel features of the invention are set forth in the appended claims. However, for purpose of explanation, several embodiments of the invention are set forth in the following figures.

FIG. **1** conceptually illustrates a graphical user interface (GUI) of the authoring platform of some embodiments.

FIG. **2** illustrates an example architecture of an authoring platform that defines behaviors.

FIG. **3** illustrates example architecture of an application built by an authoring platform of some embodiments.

FIG. **4** conceptually illustrates a process performed by some embodiments to receive an event and execute responses associated with the event.

FIG. **5** illustrates a scene of an application that is running on a device with a display area.

FIG. **6** conceptually illustrates a GUI of an authoring platform, which allows a user to graphically associate a behavior with an entity of a scene of an application being built.

FIG. **7** conceptually illustrates a GUI of an authoring platform, which allows a user to create and modify behaviors for an application being built.

FIG. **8** conceptually illustrates a GUI of an authoring platform.

FIG. **9** conceptually illustrates a GUI of an authoring platform of some embodiments.

FIG. **10** conceptually illustrates relationship between different instances of data of an application, which is built by an authoring platform of some embodiments.

FIG. **11** illustrates example architecture of an application built by an authoring platform of some embodiments.

FIG. **12** conceptually illustrates a process performed by some embodiments to receive an event and execute responses associated with the event.

FIG. **13** conceptually illustrates a process that some embodiments perform to identify behaviors that have matching event and have all conditions (if any) met.

FIG. **14** conceptually illustrates a behavior editor of the authoring platform of some embodiments.

FIG. **15** illustrates a behavior editor of some embodiments.

FIG. **16** conceptually illustrates a GUI of the authoring platform of some embodiments.

FIG. **17** conceptually illustrates a device that runs the application.

FIG. **18** conceptually illustrates a GUI of the authoring platform of some embodiments.

FIG. **19** conceptually illustrates a GUI of the authoring platform of some embodiments.

FIG. **20** conceptually illustrates a process that some embodiments perform to manage a key indices display area.

FIG. **21** illustrates merging two different animation responses of two different behaviors in the sub-key-indexed graphs of a GUI in some embodiments.

FIG. **22** conceptually illustrates a process that some embodiments performs to detect boundaries of a transparent area within an image.

FIG. **23** conceptually illustrates finding boundaries of a transparent area within an image.

FIG. **24** illustrates the software architecture of an authoring platform for building applications.

FIG. **25** conceptually illustrates an electronic system with which some embodiments of the invention are implemented.

## DETAILED DESCRIPTION

In the following detailed description of the invention, numerous details, examples, and embodiments of the invention are set forth and described. However, it will be clear and apparent to one skilled in the art that the invention is not limited to the embodiments set forth and that the invention may be practiced without some of the specific details and examples discussed.

Some embodiments of the invention provide an authoring platform for authoring interactive software applications by defining user interface (UI) behaviors, which are associations of one or more events with one or more responses. In some embodiments, an event is a user input that an authored application receives from a user of that authored application while the application is being executed. For instance, a user's clicking on a graphical item (e.g., an icon) of the application is an event that the application receives from the user. An event can also be programmatic. For instance, when a soccer game application is being executed, a graphical object representing a soccer ball colliding with another graphical object representing the goal may be programmatically defined as an event. A response is an action that the application performs in response to the received event. For instance, upon receiving the user's click, the application may enlarge the icon. Also, the soccer game application may increment the value for the score in response to an occurrence of the goal-scoring event (i.e., the soccer ball hitting the goal).

FIG. **1** conceptually illustrates a graphical user interface (GUI) **100** of the authoring platform of some embodiments.

Specifically, FIG. **1** illustrates several different GUI tools that the authoring platform provides. Using the tools, a user of the authoring platform can build interactive applications to run on devices. As shown, the GUI **100** includes a scenes pane **105**, a scene preview area **110**, a behaviors library **120**, a key indices display area **125**, and a behavior editor **130**.

The scene preview area **110** displays a scene of the application being built. In some embodiments, an application built by the authoring platform of some embodiments includes one or more scenes. A scene in some embodiments is an interactive "page" of the application. That is, each scene includes one or more entities with which a user of the application can interact. Also, the user can move from one scene to another. Entities are graphical objects of a scene displayed on a display area of a device on which the application executes.

In some embodiments, the GUI **100** allows a user to create or modify the scene by adding or deleting entities (e.g., a graphical icon) to and from the scene preview area **110**. For instance, the scene preview area **110** shows icons **111**, **112**, and **113**, which are added to the scene preview area **110** by user by dragging and dropping these icons. In some embodiments, the scene preview area **110** also allows the user of the authoring platform to simulate a run of the scene of the application. That is, the user can execute the scene of the application in the scene preview area **110**.

In some embodiments, the scene preview area **110** includes a canvas **115**. The canvas **110** in some embodiments is an area that has the size and the shape of the display area of a device on which the scenes of the application will be displayed. As will be described below in Section IV, the authoring platform of some embodiments automatically detects boundaries of the transparent area within an image that is used as a canvas.

The scenes pane **105** in some embodiments is an area of the GUI **100** that lists the scenes of an application that is being authored by the authoring platform. The scenes pane **105** lists a different set of scenes whenever a scene is added to or deleted from the application. The scenes pane **105** lists the scenes by the scenes' names in some embodiments. For instance, the scenes pane **105** displays four scene scenes **1-4** as shown. In some embodiments, when the user selects a scene in the scenes pane **105**, the GUI **100** displays the scene in the scene display area **110**.

The behaviors library **120** lists behaviors by the behaviors' names. For instance, the behaviors library **120** lists five behaviors **1-5** as shown. The GUI **100** of some embodiments allows the user of the authoring platform to graphically associate a behavior listed in the behaviors library **120** with an entity displayed in the scene preview area **115** by, for example, dragging the behavior from the behaviors library **120** and dropping onto the entity. Graphically associating a behavior with an entity of a scene will be further described below by reference to FIG. **6**.

The key indices display area **125** displays a key-indexed graph for each of the entities of a scene that is being edited in the scene preview area **110**. For instance, the key indices display area **125** displays three key-indexed graphs **126-128** for the icons **111-113**, respectively. A key-indexed graph can be expanded to sub-key-indexed graphs for properties of the corresponding entity. Key-indexed graphs and sub-key-indexed graphs for entities will be described further below by reference to FIG. **8**. In some embodiments, the GUI **100** allows the user of the authoring platform to animate properties of an entity by adding and manipulating key indices on the key-indexed graph and sub-key-indexed graphs for the entity. Also, different responses of different behaviors may be merged in the key indices display area **125**. Key indices and merging responses will be described further below by reference to FIGS. **8** and **9**.

The behavior editor **130** allows a user of the authoring platform to create and modify behaviors for an application being built by the authoring platform. As shown, the behavior editor **130** in some embodiments includes two columns **131** and **132** for listing events and responses, respectively. The events column **131** lists one or more events of the behavior being edited. The responses column **132** lists responses that are associated with events listed in the events column **132**. In some embodiments, a response in the response column is displayed in an expandable row. For instance, a response row for the response **133** is expanded to include a script editing area **134** in which the user can modify or create scripts. Further details about a behavior editor will be described below by reference to FIGS. **7**, **14**, and **15**.

As shown, the GUI **100** includes several different parts. However, not all of these different parts need to appear at a time for the GUI **100** to be functional. That is, one or more subsets of the parts of the GUI **100** may appear at a given time. Moreover, not all of these different parts need to appear in the same window. Each of the parts may have its own window that can be manipulated by the user separately from the GUI **100**. Also, one or more subsets of the parts may appear in one window. For instance, the behaviors library **120** and the behavior editor **130** may appear in the same window that is not the window of the GUI **100**.

FIG. **2** illustrates an example architecture of an authoring platform **200** that defines behaviors. The authoring platform allows a user to build an application using behaviors. A built application will perform the responses defined in the behaviors when the application receives one or more events that are defined to be associated with the behaviors. An example of such responses may be displaying an animation in response to receiving an event such as a user's click on a GUI item. The application might be an interactive game, an office application, etc. In some embodiments, the authoring platform is used to develop applications for specific devices (e.g., specific smartphones, tablets, laptops or desktops, etc.) or specific operating systems (which may run on specific devices such as smartphones, tablets, laptops, desktops, etc.). As shown, the authoring platform of some embodiments includes a user interface **205**, an event definer **210**, a response definer **215**, an events repository **220**, a responses repository **225**, an event-response associator **230**, a behaviors repository **235**, an entity-behavior associator **240**, an entities repository **245**, a scenes repository **250**, and a media library **255**.

An application built by the authoring platform of some embodiments includes one or more scenes. A scene in some embodiments includes one or more entities with which a user of the application can interact. Entities in some embodiments are graphical objects displayed on a display of a machine on which the application executes. For instance, entities may be graphical icons with which the user of the application can interact by e.g., clicking on them. The entities may represent different media pieces including icons, textual information, movies, audio clips, etc. The application displays the scenes in a certain order and each scene may have a different set of entities. When an event defined in a behavior associated with an entity occurs with respect to the entity, the authored application that includes the entity runs the response(s) associated with the event in response to the occurrence of the event.

The scenes repository **250**, which is a cache or other persistent storage medium in some embodiments, stores scenes that may become part of the authored applications. The user of the authoring platform (e.g., an application developer) creates scenes in which one or more graphical objects are displayed. The graphical objects of some embodiments may include various media pieces such as icons, textual information, movies, audio clips, etc. Within an application developed using the authoring platform **200**, these might appear as selectable items or just displayed items. As mentioned above, these graphical objects of a scene are also referred to as entities.

The media library **255** stores the media pieces. These media pieces are created by the application developers or brought into the media library **255** by the application developers in some embodiments. The media pieces may be brought into the scenes and become part of the scenes. Once the media pieces are brought into the scenes, they are represented by the entities related to the scenes. The entities repository **245** stores information regarding the media pieces that the entities represent. In some cases, an entity is stored as a data structure that has a reference to one or more media pieces that are represented by the entity. Also, this data structure in some embodiments has a reference to the behaviors that are associated with the entity as will be described below.

The authoring platform **200** provides the user with the user interface **205** through which the user can input data for authoring the application. The user can specify events and responses and associate the events and responses through the user interface. The user interface feeds the received input data to other modules of the authoring platform **200**. For instance, the user interface **205** sends the received data to the event definer **210** and the response definer **215**.

The event definer **210** defines events based on the received data. For instance, the event definer defines an event called "goalScored" which encapsulates one graphical object representing a soccer ball colliding with another graphical object representing a goal. In some embodiments, the event definer creates events by augmenting pre-defined events with conditions. Examples of pre-defined events include a mouse-down and a mouse-up, which represent user's holding down a mouse button and releasing mouse button, respectively. The conditions will provide additional constraints to meet in order to trigger responses that will be associated with the pre-defined events. The event definer **210** stores and retrieves the defined or modified events in the events repository **220**, which is a cache or other persistent storage medium in some embodiments.

The response definer **215** defines different types of responses based on the received data. The types of responses in some embodiments include a script response, an animation response, a complied code response, an audio response, etc. A script response is a script (e.g., JavaScript) that the authored application runs in response to receiving an event that is associated with the script response. An animation response is an animation that the authored application runs in response to an event that is associated with the animation response. For instance, an animation response will cause a graphical icon glow in response to user's clicking the icon. A compiled code response is an executable piece of program code that the authored application would invoke in response to receiving an event that is associated with the complied code response. For instance, the application invokes a compiled code (e.g., C++, C#, etc.) to download a file from the Internet in response to receiving a click on a graphical icon. An audio response is an audio file that the authored application would playback in response to receiving an event that is associated with the audio response.

In some embodiments, the response definer **215** defines these different types of responses in such a way that the responses of different types can communicate with each other. That is, for instance, the response definer **215** utilizes a protocol (or a format) to which the input and output data of each type of response conform so that the output of one type of response (e.g., an animation response) can be used as the input to another type of response (e.g., a script response). In other words, the response definer **215** describes the input and output data of different types of responses in a unified protocol or format so that the responses of different types can use each other's output data as the input data. For example, the response definer **215** translates the coordinates of an icon that is to be animated by an animation response from one format into a unified format. These coordinates described in the unified format are fed into a script response, which will translate the coordinates into another format that the script of the script response can use. Such unified protocol is referred to as a conformance protocol or a conformance format throughout this Specification.

In some embodiments, the conformance protocol is a format for one particular type of response. That is, the input and output of this particular type of response does not have to be translated while other types of responses have to have their input and output translated into the format for the particular type of response.

In some embodiments, the response definer **215** also defines response handlers for different types of responses. These handlers become part of authored applications along with the corresponding responses. When an authored application is running, these response handlers will parameterize the inputs and outputs of the responses using the conformance protocol so that responses of different types can communicate with each other. In this manner, the authored application can perform responses of different types that are associated with an event. For instance, an event is associated with an animation response and a script response. The animation response is defined to move a graphical icon to another position in response to an event. A handler for the animation response extracts the new position of the icon and parameterizes it into two values indicating the x and y coordinates of the center of the icon using the conformance protocol. A handler for the script response receives the two values and translates them into some other values of different types, which may be understood by the script response. The script response runs with the values translated from the values written in the conformance protocol as inputs. Further details about response handlers at runtime will be described below by reference to FIG. **3**. The response definer **215** stores defined responses and response handlers in the responses repository **225**, which is cache or other persistent storage mediums in some embodiments.

The event-response associator **230** associates an event with one or more responses based on the received data. That is, the event-response associator **230** defines behaviors according to the user's specification. In some embodiments, a behavior may include two or more events, each of which may be associated with responses. An event may be associated with responses of different types. For instance, a mouse-down event may be associated with an animation response and a script response. The event-response associator **230** stores the defined behaviors in the behaviors repository **235**, which is a cache or other persistent storage medium in some embodiments.

The entity-behavior associator **240** associates an entity with one or more behaviors based on the received data. The entity-behavior associator **240** of some embodiments stores the associations of behaviors and entities in the entities repository **245**.

FIG. **3** illustrates example architecture of an application **300** built by the authoring platform **200** described above by reference to FIG. **2**. Specifically, this figure illustrates that the application **300** performs several responses of different types in response to receiving an event from a user of the application. As shown, the built application **300** includes a user interface **305**, a behavior execution engine **315**, a scenes repository **320**, an entities repository **325**, a behaviors repository **330**. The application **300** also includes response handlers **335-345**.

The user interface **305** receives user inputs. Specifically, the user interface in some embodiments encapsulates the user's interaction with the application as event formats. For instance, when the user touches a certain part of a display device that displays a scene of the application, the user interface **305** detects the touch and generates a corresponding event (e.g., a touchdown event). In some embodiments, the user interface **305** does not detect and translate the user's interactions. Instead, the user interface **305** receives encapsulation of user's interaction from the operating system of the device on which the application is being executed. In these embodiments, the user interface **305** translates the encapsulation into an event format that the behavior execution engine **315** can understand. The user interface **305** sends events to the behavior execution engine **315**. An event in some embodiments is a piece of data that includes information regarding the type of event and location of the user interaction on the current scene, etc.

The scenes repository **320** stores all scenes that the application **300** includes. In some embodiments, the scenes are stored as data structures that have references to entities that each scene includes. The entities repository **325** stores all entities that all scenes of the application include. The behaviors repository **330** stores all behaviors (i.e., associations of events and responses) that are associated with entities of the application. The repositories **320**, **325**, and **330** each may be a cache or other persistent storage medium in some embodiments.

The behaviors execution engine **315** selects one or more behaviors based on the received event and notifies response handlers according to the responses defined in the selected behavior(s). Upon receiving an event, the behavior execution engine **315** first goes through a list of entities of the current scene to find out on which one or more entities this received event has occurred. For instance, the behavior execution engine **315** parses the received event and identifies the location within the current scene where the user has touched. The behavior execution engine **315** finds one or more entities that are placed at the identified location in the current scene. In some embodiments, an entity has properties, which include dimensions, scale, location of the entity within a scene to which the entity belongs, etc. For each of the entities found, the behaviors execution engine **315** identifies one or more behaviors that are associated with the entity. Among these identified behaviors, the behaviors execution engine **315** then finds the behaviors that match the event. That is, the behaviors execution engine **315** finds those identified behaviors that include the received event. The behaviors execution engine **315** then identifies all responses that are associated with the event for each of the behaviors found.

For each of the identified responses of a behavior, the behaviors execution engine **315** notifies a response handler for the response. The behaviors execution engine **315** in some embodiments parameterizes the received event and sends the resulting parameters to the response handlers. In some embodiments, these parameters conform to the conformance protocol which the behaviors execution engine **315** and the response handlers use to communicate with each other. In some embodiments, the behaviors execution engine **315** receives parameters from response handlers. In some cases, the behaviors execution engine **315** translates this parameter format into an event format and finds behaviors that match the event. In other cases, the behaviors execution engine **315** passes the parameters to another response handler which executes the next response to be performed by the application **300**.

The response handlers **335-345** execute responses. As described above, responses may be of different types. In some embodiments, each response handler can handle responses of different types. In other embodiments, each response handler is specific to a particular response and is able to handle only the particular response. A response handler in some embodiments translates the parameters received from the behaviors execution engine **315** into a format that the type of response that the handler is executing understands. For instance, a response handler for script responses translates parameters in the conformance protocol into values that a script response can understand. The response handler runs the script of the response, which takes the translated values as inputs.

In some embodiments, a response handler translates the result or output of the executed response into parameters in the conformance protocol. The response handler may pass the parameters back to the behaviors execution engine **315** or send the parameters to another response handler. The response handler that received the parameters then translates the parameters into inputs to the responses that this handler handles and then executes the responses. For instance, the response handler **335** handles responses of type A (e.g., an animation response). Parameters **365** that the response handler **335** receives do not include a next response to be executed. The response handler **335** translates the output of running the response **1** of type A into parameters **370** in the conformance protocol and sends them back to the behavior's execution engine **315**. On the other hand, the parameters **375** includes a chain of responses to be executed in response to the received event. The response handler **340** translates the parameters **375** into inputs for response **2** of type B (e.g., a script response) and executes the response **2**. The response handler **340** then translates the output of the response **2** into the parameters **380** in the conformance protocol. Since the response handler **340** knows the next response in the chain of responses to be executed, the response handler **340** sends the parameters **380** to the response handler **345** of type C.

Some embodiments execute responses in parallel in some cases. For instance, the response handler **335** and **340** may receive parameters **365** and **375** independently from the behavior execution engine **315** and execute the responses **1** and **2** in parallel. In other cases, some embodiments execute responses sequentially. For instance, as described above, the response handlers **340** and **345** execute the responses **2** and **3** sequentially when they receive the parameters **365** and **375**, which are defined as being sequential in a chain of responses to be executed.

An example operation of the application **300** will now be described by reference to FIG. **4**. FIG. **4** conceptually illustrates a process **400** performed by some embodiments to receive an event and execute responses associated with the event. In some embodiments, the application **300** performs the process **400**. The process **400** begins by receiving (at **405**) an event. For instance, the application **300** receives an event **310**. The event **310** in this example indicates that the user has touched a graphical icon placed in a certain location of the current scene that is being displayed for the user.

Next, the process **400** finds (at **410**) one or more entities to which the received event applies. The process uses information included in the event to identify the entities of the current scene to which the event applies. For instance, the application **300** goes through a list of entities of the current scene and finds out to which entities the event **310** has occurred. In this example, the application **300** identifies the graphical icon as the entity on which the event **310** has occurred.

The process **400** then finds (at **415**) one or more behaviors that include the received event for each of the entities found at **410**. The process in some embodiments first identifies all behaviors that are associated with an identified entity. As described above, entities of the application in some embodiments includes references to the behaviors that are associated with the entity. The process uses the references to identify all behaviors. The process then finds those identified behaviors that include the received event. In this manner, the process finds only the behaviors that are associated with an identified entity and that include the received event. In FIG. **3**, the application **300** finds one behavior (not shown) that is associated with the graphical icon and that includes the event **310**.

Next, the process identifies (at **420**) all responses that are associated with the received event. The process identifies the responses from the behaviors found at **415**. For instance, the application **300** identifies two responses, i.e., responses **2** and **3**, that are associated with the one behavior that is associated with the graphical icon and includes the event **310**.

The process then executes (at **425**) all responses identified at **420**. These responses include all responses that are associated with the received event in all behaviors. These behaviors are in turn associated with all entities to which the received event applies. The process in some embodiments may execute responses that are independent of each other in parallel. Also, the process may sequentially execute responses that are not independent of each other (e.g., chained responses).

In order to execute these identified responses, the process translates the received event into a format that a response type understands. For instance, the application **300** converts the event **310** into parameters in the conformance protocol and then translates the parameters to inputs to the response **2**, which is of response type B. The application executes the response **2** using the inputs and then translates the output of the response **2** into the parameters **380** in the conformance protocol. The application **300** then translates the parameters **380** into inputs that the response **3** of response type **3** would understand. The application **300** then executes the response **3** with the inputs.

FIG. **5** illustrates a scene of an application that is running on a device with a display area **520**. Specifically, this figure illustrates in three different stages **505-515** that the application performs several responses in response to receiving several events. The application includes a scene that has six icons including an icon **525**. The application includes behaviors **1** and **2** that are associated with the icon **525**.

The behavior **1** is an association of one event and one animation response. The event in the behavior **1** is a touchdown, which represents user's placing her finger on the display area **520**. The response in the behavior **1** is an animation response called "glow" which, when executed, makes the entity associated with the behavior **1** glow. The behavior **2** is also an association of one event and one animation response. The event in the behavior **2** is a touchup, which represents user's lifting her finger from the display area **520**. The response in the behavior **2** is an animation response called "bulge" which, when executed, enlarges the entity associated with the behavior **2**.

The first stage **505** shows the display area **520** displaying the icon **525** along with five other icons of the current scene. At the second stage **510**, the user touches the icon **525** with a finger. Thus, the application has received a touchdown event. With the received event, which includes information about the location of the display area **520**, the application identifies that the icon **525** is the entity on which the touchdown event has occurred. The application then finds out that the behaviors **1** and **2** are the only two behaviors that are associated with the icon **525**. The application goes through these two behaviors' events and determines that only the behavior **1** has the matching event, a touchdown event. As a result, the application executes only the glow response of the behavior **1**. As indicated in the stage **510**, the icon **525** is glowing.

At the third stage **515**, the user has lifted her finger. As the user lifts her finger up from the display area **520**, the application receives the touchup event. The application again identifies that the icon **505** is the entity on which the touchup event has occurred. The application then finds out that the behaviors **1** and **2** are the two behaviors that are associated with the icon **525**. The application goes through the two behaviors' events and determines that only the behavior **2** has the matching event, a touchup event. The application thus executes only the bulge response of the behavior **2**. As shown at the third stage **515**, the icon **515** is enlarged as the finger is lifted up from the display area **520**.

FIG. **6** conceptually illustrates a graphical user interface (GUI) **600** of an authoring platform, which allows a user to graphically associate a behavior with an entity of a scene of an application being built. Specifically, this figures illustrates in two different stages **605** and **610** that behavior **2** is getting associated with an icon **625**. As shown, the GUI **600** includes a scene preview area **615** and a behaviors library **620**.

The scene preview area **615** displays a scene of the application being built. The user can create or modify the scene by adding or deleting entities (e.g., a graphical icon) to and from the scene preview area **615**. In some embodiments, the scene preview area **615** also allows the user to simulate running the scene of the application. That is, the user can playback the scene in the scene preview area **615**.

The behaviors library **620** displays a list of behaviors that are represented as graphical objects. These behaviors can be associated with entities displayed in the scene preview area **615**. In some embodiments, the behaviors library **620** displays predefined behaviors. The behaviors library **620** also allows the user of the authoring platform to add new behaviors. In some embodiments, the GUI **600** allows the user of the authoring platform to associate an entity and a behavior by dragging a graphical object representing the behavior and dropping it onto an entity displayed in the scene preview area **615**.

At the first stage **605**, the user of the authoring platform selects behavior **2**. The user can select a behavior displayed in the behaviors library. This selection may involve clicking a mouse button or tapping a touchscreen to select a graphical object representing a behavior, selecting an option through keyboard input, etc.

At the second stage **610**, the user of the authoring platform drags behavior **2** over the icon **625**. In some embodiments, as the user moves the cursor while a behavior is selected, the GUI shows the graphical object (e.g., a gear-looking icon) along the path of the cursor in order to provide a visual cue. When the graphical object hovers near an icon, the GUI may provide another visual cue (e.g., a different background color for the icon) to indicate that the behavior represented by the graphical object will be associated with the icon once the graphical object is dropped there. The user drops the graphical object representing the behavior **2** onto the icon **625**. As a result, the icon **625** is associated with the behavior **2**. That is, when an authored application that includes this scene is executed, the application will run the response defined in the behavior **2** upon receiving an event that is associated with the response in the behavior **2** and the icon **625**.

FIG. **7** conceptually illustrates the GUI **600** of the authoring platform, which allows a user to create and modify behaviors for an application being built. Specifically, this figure illustrates in two different stages **705** and **710** launching a behavior editor **725**.

At the first stage **705**, the user of the authoring platform selects behavior **1** to launch a behavior editor. The GUI **600** in some embodiments displays a behavior editor when the user selects a behavior displayed in the behaviors library **620**. This selection may involve clicking a mouse button or tapping a touchscreen to select a graphical object representing a behavior, selecting an option through keyboard input, etc. For instance, the user may double-click on a graphical object representing a behavior to launch a behavior editor.

At the second stage **710**, the GUI **600** displays the behavior editor **725**. As shown, the behavior editor **725** in some embodiments includes two columns for showing events and responses. The events column lists one or more events that are defined in the behavior being edited. The responses column lists responses associated with events listed in the events column. In some embodiments, each response in the response column is displayed in an expandable row. For instance, a response row for the script response **730** is expanded to include the script editing area in which the user can modify or create scripts. In some embodiments, the behavior editor occupies a portion or the entirety of the GUI **600**. In other embodiments, the behavior editor may be a separate window that can be separately manipulated from the GUI **600**.

FIG. **8** conceptually illustrates a GUI **800** of an authoring platform. Specifically, this figure illustrates in two different stages **805** and **810** that a key-indexed graph for an entity of a scene can be expanded to sub-key-indexed graphs for the properties of the entity. As shown, the GUI **800** includes a scene preview area **815** and the key indices display area **820**.

The scene preview area **815** is similar to the scene preview area **615** described above by reference to FIG. **6**. The key indices display area **820** displays a key-indexed graph for each of the entities that belong to a scene that is being edited in the authoring platform. In some embodiments, the GUI **800** allows the user of the authoring platform to place handles for key indices (e.g., keyframes) on the key-indexed graph. A key index pair represents a start or an end of an animation for an entity (e.g., an icon) of a scene. For instance, the first key index of a key index pair defines a first location of the entity within the scene at the beginning of a time period and the second key index of the key index pair may define a second location of the entity within the scene at the end of the time period. When the scene is played back for the time period represented by the two key indices of the pair, the entity moves from the first location at the beginning of the time period to the second location at the end of the time period. In some embodiments, the intermediate positions of the icon being moved during the time period are interpolated based on the first and the second positions. Thus, an animation may be defined as a set of key indices placed along a key-indexed graph. In this manner, key indices in some embodiments are used like the way keyframes are used for a video file (e.g., for defining the starting and ending points of any smooth transition.)

At the first stage **805**, the scene preview area **815** displays three icons of a scene that is being edited. The key indices display area **820** displays three key-indexed graphs of the three icons **1-3**. The key-indexed graphs for the icons **1** and **2** each have a key index depicted as a black dot in the figure. The hollow dots at the end of key-indexed graphs represent the end of key-indexed graph for the three icons. In some embodiments, the user selects the key-indexed graph for the icon **1** to expand this key-indexed graph into sub-key-indexed graphs. This selection may involve clicking a mouse button or tapping a touchscreen to select the key-indexed graph, selecting an option through keyboard input, etc. For instance, the user may click on the black triangle to cause the key indices display area **820** to display sub-key-indexed graphs for the properties of the icon **1**. The properties of an entity in some embodiments include a position, a scale, a rotation, a color, etc. to name a few.

At the second stage **810**, the GUI has expanded the key-indexed graph for the icon **1** into sub-key-indexed graphs for some of the properties of the icon **1**. Not all of sub-key-indexed graphs for all the properties are depicted in this figure for simplicity of description. By providing a sub-key-indexed graph for each of the properties of an entity, the GUI **800** allows the user to control each property of the entity by adding and editing key indices to the sub-key-indexed graph. For instance, the user can have the color of an entity to change gradually by introducing a key index in the sub-key-indexed graph for the color property of the entity.

FIG. **9** conceptually illustrates a GUI **900** of an authoring platform of some embodiments. Specifically, this figure illustrates in four different stages **905-920** that two behaviors including animation responses can be combined in the key-indexed graphs. As shown, the GUI **900** includes a scene preview area **925**, a behaviors library **930**, and a key indices display area **935**. The scene preview area **925** is similar to the scene preview area **615** described above by reference to FIG. **6**. The behaviors library **930** is similar to the behaviors library **620** described above by reference to FIG. **6**. The key indices display area **935** is similar to the key indices display area **820** described above by reference to FIG. **8**.

The authoring platform of some embodiments allows for combining two animation responses in the key-indexed graphs when the responses are associated with the same event. As described above, an animation response may be represented as a set of key indices for one or more entities of a scene. Combining several animation responses in the key-indexed graphs therefore means combining the key indices of different responses in some embodiments. The GUI **800** allows the user to combine responses in the key-indexed graphs by dragging a behavior from the behaviors library and dropping the behavior on the key indices display area near the key-indexed graphs of another response of another behavior.

When the response that is being dropped does not have the same triggering event as the response that is being shown in the key indices display area, the GUI **900** may prompt a message indicating that the response that is being dropped may not be combined. Many other combinations of key indices may occur and different embodiments treat these combinations differently. For instance, when a first key index of a first response overlaps with an existing second key index of a second response, the authoring platform of different embodiments may (1) keep the second key index only, (2) keep the first key index only, or (3) composite the first and the second key indices (e.g., by taking a mean of the values represented by the two key indices). When different key indices of different responses fall in the same key-indexed graph, the authoring platform of different embodiments may (1) keep the existing key indices only, (2) keep the key indices of the response being dropped, or (3) keep all of the key indices.

At the first stage **905**, the key indices display area **935** is displaying sub-key-indexed graphs for the properties of the icon **1**. Particularly, the sub-key-indexed graphs are showing an animation response of a behavior that is associated with the icon **1**. The icon **1** is associated with behavior **1**, which includes an animation response. This animation response adjusts the position property of the entity with which the behavior **1** is associated. As shown, the sub-key-indexed graph for the position property of the icon **1** has a key index around the middle of the time period that the animation response spans. When the scene receives an event that is associated with this animation response of behavior **1**, the icon **1** will move to the position specified by the key index in response to receiving the event.

At the second stage **910**, the user of the authoring platform selects behavior **4**. This selection may involve clicking a mouse button or tapping a touchscreen to select a graphical object representing a behavior, selecting an option through keyboard input, etc. The behavior **4** includes the same event as the event that the response of behavior **1** is associated with. The behavior **4** also has an animation response that is associated with that event. This animation response adjusts the scale property of the entity with which the behavior **4** is associated.

At the third stage **915**, the user drags behavior **4** and drops onto the key indices display area **935** which is currently showing the animation response of the behavior **1**. The fourth stage **920** shows that a key index has appeared on the sub-key-indexed graph for the scale property of the icon **1** as a result of dropping behavior **4** onto the key indices display area **935**.

FIG. **9** illustrates merging responses in the key-indexed graphs by dropping behaviors onto the key indices display area near sub-key-indexed graphs for a particular entity. However, the key indices display area does not have to be showing sub-key-indexed graphs for merging to happen. Also, the authoring platform of some embodiment allows for merging responses in different ways instead of or in conjunction with dropping behavior onto the key indices display area. For instance, the authoring platform of some embodiments allows the user to merge responses by dropping behaviors onto an entity displayed in the scene preview area.

Several detailed embodiments of the invention are described in the sections below. Section I describes the conformance protocol and architecture of an authored application of some embodiments. Section II describes GUI tools of the authoring platform of some embodiments, including a behavior editor. Section III describes merging responses in the key indices display area of some embodiments. Section IV then describes automatic detection of boundaries of transparent area within an image. Next, Section V describes architecture of the authoring platform of some embodiments. Finally, Section VI describes an electronic system that implements some embodiments of the invention.

## I. Conformance Protocol

### A. Data Relationship

The application authored by the authoring platform of some embodiments includes one or more scenes. As described above, a scene includes one or more entities, which are graphical objects with which a user of the application can interact. A scene has spatial properties as well as temporal properties. That is, a scene has a border in which to hold the entities and has duration for displaying the scene. The application displays a scene on a display device for a machine on which the application is running. The application processes the user's interactions with the entities of the scene, which may involve displaying another scene that the application includes.

FIG. **10** conceptually illustrates relationship between different instances of data of an application **1000**, which is built by an authoring platform of some embodiments. Specifically, this figure illustrates that the entities that the application includes are associated with behaviors. The application therefore runs responses when the application receives events that are associated with the responses.

FIG. **10** illustrates a scene **1005** that the application has. Other scenes that the application includes are not depicted for simplicity of description. The scene **1005** includes entities **610-625**. An entity also has spatial properties and temporal properties. Spatial properties of an entity include a scale, rotation, color, position, opacity, three dimensional coordinates, etc. Temporal properties of an entity include duration for displaying the entity.

Entities of a scene in some embodiments form a hierarchy such as a tree-like structure. As shown, the scene **1005** has a root entity **1010**, which has two sub-entities **1015** and **1020**. The entity **1020** has two sub-entities **1025** and **1030**. An entity in some embodiments appears behind (or, is a layer behind) its sub-entities when the scene is displayed. In some cases, an entity may spatially enclose its sub-entities. The entities **1015** and **1020** are peers. So are the entities **1025** and **1030**. Peer entities in some embodiments are entities that are not spatially enclosed by each other. The entities in some embodiments dynamically form a hierarchy. That is, the hierarchy may be changed as the entities may appear or disappear from the scene while the application is running.

As described above, an entity of a scene can be associated with one or more behaviors. The association of behaviors and events are made during the application was being built by an authoring platform of some embodiments. Each behavior includes or is associated with an event. As described above, a behavior in some embodiments is a data structure that has references to events and responses that are associated with the events. Each event of a behavior is associated with one or more responses. As shown, the entity **1015** is associated with behaviors **1035**. A behavior **1040** is associated with events **1045**. An event **1050** is associated with responses **1055**. The responses **1055** conceptually form a chain to indicate that the responses **1055** are performed in series when the event **1050** occurs on the entity **1015**. Moreover, as described above, when an event of a behavior is associated with responses that are independent of each other (e.g., not in a chain), these responses are performed in parallel when such event occurs.

B. Authored Application Architecture

FIG. **11** illustrates example architecture of an application **1100** built by an authoring platform of some embodiments. Specifically, this figure illustrates that the application **1100** performs several responses of different types in response to receiving an event from a user of the application. As shown, the built application **1100** includes a user interface **1105**, an event detector **1110**, a behavior execution engine **1120**, an events repository **1150**, a scenes repository **1152**, an entities repository **1155**, a behaviors repository **1160**, and a responses repository **1162**. The application **1100** also includes response handlers **1175**, **1195**, and **1196**.

The user interface **1105** receives user inputs. Specifically, the user interface in some embodiments encapsulates the user's interaction with the application **1100**. For instance, when user touches a certain part of a display device that displays a scene of the application, the user interface **1105** detects the touch and generates data indicating the touch. In some embodiments, the user interface **1105** does not detect and translate the user's interactions. Instead, the user interface **1105** receives encapsulation of user's interaction from the operating system of the device on which the application **1100** is being executed. The user interface **1105** sends the encapsulation of the user's interaction to the event detector **1110**.

The event detector **1110** receives the encapsulation of the user interaction from the user interface **1105** and translates it into an event format that the behavior execution engine **1120** can understand. The event detector **1110** receives other data from other components (not shown) of the application **1100** and determines whether these data can constitute an event. For instance, when an entity disappears from the current scene being displayed, the event detector **1110** detects the disappearance as form of data and determines whether this disappearance should be translated into an event to send to the behavior's execution engine **1120**. In some embodiments, the event detector **1110** looks up the event definitions stored in the events repository **1150** in order to make such determination.

The events repository **1150** stores event definitions of possible events that may occur for the scenes of the applications. The scenes repository **1152** and the entities repository **1155** are similar to the scenes repository **320** and the entities repository **325**, respectively, described above by reference to FIG. **3**. The behaviors repository **1160** is similar to the behaviors repository **330** described above by reference to FIG. **3** except that the behaviors stored in the behaviors repository **1160** includes references to events and responses stored in the events repository **1150** and the responses repository **1162**. The behaviors repository **1160** stores all behaviors (i.e., associations of events and responses) that are associated with entities of the application. The repositories **1150**, **1152**, **1155**, **1160**, and **1162** each may be a cache or other persistent storage medium in some embodiments.

The behaviors execution engine **1120** is similar to the behaviors execution engine **315** described above by reference to FIG. **3**. In addition, the behaviors execution engine **1120** includes an entity finder **1125**, a behavior finder **1130**, a conditions checker **1135**, a response manager **1140**, and an event converter **1145**.

The entity finder **1125** receives an event from the event detector **1110** and finds one or more entities on which the event has occurred. The entity finder **1125** in some embodiments uses the coordinates of the event in the current scene to find the entities on which the event occurred. The entity finder **1125** may also walk through entity hierarchy (e.g., by using a breadth-first or a depth-first search) formed by the entities. An example entity hierarchy was described above by reference to FIG. **10**.

The behavior finder **1130** receives a list of entities on which the event has occurred. For each of the entities in the list, the behavior finder **1130** identifies all behaviors that are associated with the entity. Then the behavior finder **1130** examines each identified behavior to see which behavior refers to (or includes) an event that matches the received event. When the matching event of a behavior has additional conditions to meet in order to trigger responses that are associated with the event, the behavior finder **1130** uses the condition checker **1135** to determine whether these conditions are met. As described above, the authoring platform of some embodiments allows a user of the platform to define these additional conditions to meet. An example condition may be whether the entity has a certain name. More details about defining and adding conditions to the event will be described further below.

When all conditions (if any) are met, the finder adds this behavior to a list of behaviors from which to identify responses to execute. This list of behaviors then includes the behaviors that have an event that matches the received event and have all of the conditions (if any) met. For each of the behaviors in the behaviors list, the behavior finder **1130** identifies all responses that are associated with the matching event of the behavior. The behavior finder **1130** then sends the identified responses to the response manager **1140**.

The response manager **1140** converts the received event into parameters that conform to a protocol (or a format) using the event converter **1145**. As mentioned above, this protocol is referred to as the conformance protocol. The parameters formatted in the conformance protocol are understood by the behavior execution engine **1120** and different types of response handlers. In other words, this conformance protocol enables different types of responses to communicate with each other.

The response manager **1140** sends the parameters converted from the received event to a response handler for each of the responses identified by the behavior finder **1130**. The response manager **1140** also sends additional parameters in the conformance protocol. The additional parameters include a parameter identifying the response to be executed by the response handler. When the received event is associated with a chain of responses for a behavior, the response manager **1140** sends all these parameters (i.e., parameters converted from the received event and additional parameters) to the response hander for the first response of the chain.

The response handlers **1175**, **1195**, and **1196** are similar to the response handlers **335**-**345**, respectively, described above by reference to FIG. **3**. In addition, the response handler **1175** includes an input converter **1180**, a response execution engine **1185**, and an output converter **1190**. The input converter **1180** converts the parameters received from the response manager **1140** into a format that a type of response can understand. For instance, when the response handler **1175** handles a script response, the input converter **1180** translates the received parameters in the conformance protocol into values that the script response can understand. The response execution engine **1185** identifies a response to execute based on the received parameters and then executes the response with the inputs converted from the received parameters.

The response execution engine **1185** in some embodiments retrieves response definitions (e.g., script) from the responses repository **1162**. The response execution engine **1185** then sends the output of the executed response to the output converter **1190** in some embodiments. In other embodiments, the response execution engine **1185** does not send anything to the output converter **1190**. That is, these embodiments do not include or use the output converter **1190**.

The output converter **1190** converts the output into parameters in the conformance protocol. The output converter **1190** in some embodiments sends the parameters to the response manager **1140**. In some cases, the output converter **1190** sends the parameters to a response handler for a response that is next in the chain of responses triggered by the received event. When the next response in the chain is of the same type as the response just executed, the response handler **1175** in some embodiments may bypass the conversion of the output into the conformance protocol parameters and use the output of the executed response as inputs to the next response in the chain.

When the response manager **1140** receives parameters from a response handler, the response manager **1140** determines whether there is another response in a chain of responses that needs to be executed. When such response exists, the response manager **1140** relays the received parameters along with additional parameters to the response handler for that next response. When such response does not exist (i.e., when the previously executed response is the last response in the chain or is not part of a chain of responses), the response manager **1140** in some embodiments converts the parameters to an event format using the event converter **1145**. The response manager **1140** of these embodiments then sends the event to the entity finder **1125** so that the entity finder **1125** can determine whether this event triggers any other responses.

An example operation of the application **1100** will be described now by reference to FIG. **12**. FIG. **12** conceptually illustrates a process **1200** performed by some embodiments to receive an event and execute responses associated with the event. The process **1200** may be performed by an application such as the application **1100** that is built by an authoring platform of some embodiments. The process **1200** starts as the application starts playing back a scene.

The process **1200** begins by determining (at **1205**) whether an event has occurred. In some cases, the process **1200** detects an event when the user interacts with one or more entities of the scene by touching or clicking the entities of the scene. In other cases, the process **1200** detects an event when one or more entities of the scene change. Such changes may include appearance or disappearance of an entity of a scene. As described above, some such changes may not constitute an event. The process determines whether the changes could make an event by going through the event definitions. For instance, the application **1100** looks up the event definitions stored in the events repository **1150** in order to make such determination. The application **1100** detects an event **1115**, which is a touchdown event.

When the process determines (at **1205**) that no event has occurred, the process **1200** then determines whether to end **1210**. The process **1200** ends when the application plays another scene or when the application is closing down. If at **1210** the process determines that it should end, the process ends. Otherwise, the process **1200** loops back to **1205** to determine whether an event has occurred.

When the process determines (at **1205**) that an event has occurred, the process identifies (at **1215**) the entities of the scene on which the event has occurred. The process in some embodiments uses the location where the event has occurred to identify such entities. For instance, the application **1100** goes through an entity hierarchy to identify all entities that overlaps the location of the touchdown event **1115**. The application **1100** identifies an image as the entity on the touchdown event. That is, the user of the application **1100** is touching the image displayed.

Next at **1220**, the process **1200** selects an entity that is identified at **1215** and identifies all behaviors that are associated with the selected entity. The process then determines (at **1225**) whether any of the identified behaviors matches the event that has occurred on the selected entity. That is, the process determines whether each of the identified behaviors has an event that matches the event that has occurred on the selected entity. The process examines each identified behavior to see the behavior refers to (or includes) an event that matches the event occurred. For example, the process **1200** selects an image on which a touchdown event occurred. The process **1200** identifies two behaviors that are associated with the image. Each of these two behaviors includes a touchdown event. In the first behavior, the touchdown event is associated with an animation response, which, when executed, will enlarge the image by 200 percent. In the second behavior, the touchdown event is associated with another animation response, which, when executed, makes the image glow. Accordingly, the process **1200** determines that these two behaviors have an event that matches the event occurred.

In some embodiments, the process **1200** also checks for the conditions that might be augmented to the matching event. The conditions checking process will be described in detail further below by reference to FIG. **13**.

When the process **1200** determines (at **1225**) that none of the behaviors has a matching event or satisfies all the conditions (if any). When none of the behaviors has a matching event or satisfies all the conditions, the process then proceeds to **1250**, which will be described further below.

When the process **1200** determines (at **1225**) that there are one or more behaviors that have a matching event and have all of the conditions (if any) met, the process selects (at **1230**) one of the behaviors and identifies all responses that are associated with the matching event. At **1235**, process **1200** then selects and executes a next response. In some cases, this next response is the first of a series of responses that is associated with the matching event of the selected behavior. In the example, the process **1200** selects the first behavior of the two behaviors identified. Then, the application **1100** executes the animation response, causing the image to enlarge by 200%.

Next, the process **1200** determines (at **1240**) whether there are more responses that are associated with the matching event of the selected behavior that have not been executed. When the process **1200** determines (at **1240**) that there are more such responses, the process **1200** loops back to **1235** to select and execute the next response. Otherwise, the process **1200** proceeds to **1245** to determine whether there are more identified behaviors that have not been processed yet. In the example, the process **1200** selects the second behavior of the two behaviors identified. The process **1200** then executes the animation response to cause the image to glow. In some embodiments, the process **1200** may execute the animation responses of the first and the second behaviors in parallel rather than sequentially because the two animation responses are not in the same chain of responses of one behavior.

When the process determines (at **1245**) that there are more identified behaviors that have not been processed yet, the process **1200** loops back to **1230** to select another identified behavior and identify all responses that are associated with the matching event of this behavior. Otherwise, the process proceeds to **1255** to determine whether there are more identified entities remain to be processed. When the process **1200** determines (at **1250**) that there are more identified entities to process, the process **1200** loops back to **1220** to select another identified entity. Otherwise, the process **1200** ends.

FIG. **13** conceptually illustrates a process **1300** that some embodiments perform to identify behaviors that have matching event and have all conditions (if any) met. The process **1300** may be performed by an application that is built by the authoring platform of some embodiments. The process begins by receiving (at **1305**) an event that has occurred on an entity of a scene and one or more behaviors that are associated with the entity.

Next, the process **1300** selects (at **1310**) a next behavior from the behaviors received at **1305**. The process **1300** then determines (at **1315**) whether the selected behavior has an event that matches the received event. In some embodiments, the process **1300** compares the event data defined in the behavior and the received event data. When the process **1300** determines (at **1315**) that the selected behavior does not have a matching event, the process **1300** proceeds to **1335**, which will be described further below.

When the process **1300** determines (at **1315**) that the selected behavior has a matching event, the process **1300** then determines (at **1320**) whether the matching event has conditions to meet to trigger responses that are associated with the matching event. When the process **1300** determines (at **1320**) that the matching event does not have any conditions to meet, the process **1300** proceeds to **1330** to identify the selected behavior as a behavior of which to execute responses. Otherwise, the process **1300** proceeds to **1325** to determine whether all conditions are met. The process **1300** checks each condition. An example condition may be whether the entity has a certain color value. The process determines that this condition is met when the entity has that color value.

When the process **1300** determines (at **1325**) that all conditions are met, the process **1300** proceeds to **1330** and identifies the selected behavior as a behavior, of which to execute responses. When the process **1300** determines (at **1325**) that not all conditions are met, the process **1300** determines (at **1335**) whether there are more received behaviors left to process. When the process **1300** determines (at **1335**) that there are more such behaviors left, the process loops back to **1310** to select the next received behavior. Otherwise, the process ends.

Having described the relationship between instances of scenes, entities, behaviors, events, and responses that an authored application uses at runtime and the operations of the authored application at runtime, the next Section II will now describe several tools for defining scenes, entities, behaviors, events, and responses.

II. GUI Tools of Authoring Platform

A. Behavior Editor

FIG. **14** conceptually illustrates a behavior editor **1400** of the authoring platform of some embodiments. The behavior editor **1400** allows a user of the authoring platform to create and modify behaviors for an application being built by the authoring platform. As shown, the behavior editor **1400** includes a behaviors pane **1405**, an events column **1420**, a responses column **1425**, and a script editing area **1440**. The behavior editor **1400** also includes add and delete buttons **1410** and **1430** and text panes **1415** and **1435**. FIG. **14** also illustrates five behaviors in the behaviors pane **1405**, five events in the events column **1420**, one response in the responses column **1425**, and a script code snippet in the script editing area **1440** as examples.

The behavior editor **1400** may be launched from a GUI of the authoring platform. For instance, the behavior editor **1400** can be launched by selecting a behavior listed in a behaviors library such as the behaviors library **620** of the GUI **600** described above by reference to FIGS. **6** and **7**. The behavior editor **1400** may occupy a portion or the entirety of the GUI from which the behavior editor **1400** launched. The behavior editor may also be a separate window from the GUI. This separate window may be separately manipulated (i.e., closed, opened, resized, etc.). Also, in some embodiments, the behaviors pane **1405**, the events column **1420**, and the responses column **1425** are within the same behavior editor **1400** window as shown. In other embodiments, one or more of the behaviors pane **1405**, the events column **1420**, and the responses column **1425** may be a separate window. In some other embodiments, two of the behaviors pane **1405**, the events column **1420**, and the responses column **1425** may be in the same window.

The behaviors pane **1405** lists behaviors that can be edited in the behavior editor **1400**. The behavior editor **1400** allows the user of the authoring platform to add a behavior to the behaviors pane **1405**. For instance, the user can click on the plus sign of the add and delete button **1410** to add a behavior.

A graphical object (e.g., a gear-looking icon) appears in the behaviors pane when a new behavior is added in some embodiments. The behavior added in this manner may initially be an empty one with a default name. Events and responses may be added or defined through the events column **1420** and the responses column **1425**. The user can also remove a behavior by selecting the behavior and clicking on the minus sign of the add and delete button **1410**.

The behavior editor **1400** also allows the user to import and export behaviors to and from the behaviors pane **1405**. The users may exchange behaviors with each other by exporting the behaviors to files and exchanging the files. The behaviors pane **1405** may also include predefined behaviors, which in some embodiments have been provided as part of the authoring platform. In some embodiments, the behaviors added to or deleted from the behaviors pane **1405** will also be added to or deleted from a behaviors library, such as the behaviors library **620**. That is, the behaviors pane of a behavior editor and a behaviors library will maintain the same list of behaviors.

In order to edit a behavior, the user of the authoring platform can select a behavior in the behaviors pane **1405**. This selection may involve clicking a mouse button or tapping a touchscreen to select a graphical object representing a behavior, selecting an option through keyboard input, etc. The behaviors pane **1405** provides a visual cue (e.g., different background color, bolding the name of the selected behavior, etc.) to indicate the selection of the behavior. For instance, the name of the "To Scene" behavior is bolded to indicate the selection of that behavior as shown.

When a behavior is selected in the behaviors pane **1405**, the events column **1420** lists one or more events of the selected behavior. In some embodiments, the events column **1420** may list predefined events by default when the selected behavior is an empty behavior. The behavior editor **1400** also allows the user to create or add event definitions in the events column.

The five events examples listed in the events column **1420** define different interactions of the user with the entity with which the selected behavior would be associated. For instance, the "Touch Down" event is a touchdown event, which represents the user's placing a finger (or, pressing down a mouse button) on the entity. The "Touch Moved" event is an event that represents the user's moving the finger while touching the entity. The "Touch Up" event is a touchup event, which represents the user's lifting the finger from the entity. The "Enter Frame" event is an event that represents the user's moving the finger into the area occupied by the entity while keeping the finger's contact that was initiated outside the area. The "Exit Frame" event is an event that represents the user's moving the finger out of the area occupied by the entity while keeping the finger's contact.

In order to view the responses that are associated with an event, the user of the authoring platform can select an event in the events column **1420**. This selection may involve clicking a mouse button or tapping a touchscreen to select the name of the event, selecting an option through keyboard input, etc. The events column **1420** provides a visual cue (e.g., different background color, bolding the name of the selected behavior, etc.) to indicate the selection of the event. For instance, the name of the "Touch Up" event is bolded to indicate the selection of that event as shown.

When an event is selected in the events column **1420**, the responses column **1425** lists one or more responses that are associated with the selected event. For instance, the responses column **1425** displays the "Curl to Scene" response, which is a script response that is associated with the "Touch Up" event. The behavior editor **1400** also allows the user to create or add response definitions in the responses column **1425**. For instance, the behavior editor **1400** allows the user of the authoring platform to add a response by clicking on the plus sign of the add and delete button **1430**. A default response name appears in the responses column **1425** when a new response is added in some embodiments. The response added in this manner may initially be an empty one and do not have a type. The user may specify the response's type (e.g., a script response, an animation response, a complied code response, etc.) by, for example, prompting a dropdown menu and selecting an item representing a response type. The user can also remove a response by selecting the response in the responses column **1425** and clicking on the minus sign of the add and delete button **1430**.

The behavior editor **1400** in some embodiments provides the script editing area **1440** in which the user can modify a script response. In order to edit a script response, the user can select a response listed in the responses column **1425**. This selection may involve clicking a mouse button or tapping a touchscreen to select the name of the response, selecting an option through keyboard input, etc. When the response selected in the responses column **1425** is a script response, the behavior editor **1400** displays the script code on the script editing area **1440**. In some cases, the behavior editor **1400** may display nothing or some default script snippet if the selected script response is an empty response.

The example script shown in the script editing area **1440** is a JavaScript snippet that defines the use of "destinationScene" variable. This variable can be visually linked to a scene. Visually linking a variable to a scene will be described below by reference to FIG. **16**. This example script, when executed, causes the application to change the current scene to another scene upon receiving a touchup event on an entity with which "To Scene" behavior is associated.

The behavior editor **1400** in some embodiments provide other means (not shown) of editing for other types of responses. For instance, the behavior editor may launch or open within the behavior editor a key indices display area, such as the key indices display area of FIG. **9**, for editing an animation response. Also, the behavior editor **1400** in some embodiments allows the user to change the names of behaviors and responses by typing in desired names in the text panes **1415** and **1435**, respectively.

FIG. **15** illustrates the behavior editor **1400** of FIG. **14**. Specifically, FIG. **15** illustrates that the behavior editor **1400** allows the user of the authoring platform to add and edit conditions to an event. As described above, these conditions are associated with an event of a behavior and they have to be met in order for the event to trigger the responses associated with the event. In some embodiments, the conditions may relate to the properties of an entity with which the selected behavior is associated. For instance, the name of the entity may be a condition.

In some embodiments, the behavior editor **1400** provides a predicate editor **1505** for defining and adding conditions. The predicate editor **1505** in some embodiments includes a group of dropdown menus and a text pane. For instance, the predicate editor includes four drop down menus **1510** and a text pane **1515**. Each dropdown menu contains a list of items that represent certain values. These items and values are predefined in some embodiments. The user can define different conditions by selecting different combinations of items from these dropdown menus and typing in desired texts. For instance, the combinations of the items and the typed in text as shown, "Any," "of the following are true," "name," "contains," "clock," constitute a condition requiring that the name of the entity should be "clock" in order for the touchup event on the entity to trigger the responses associated with the touchup event. The encircled plus and minus signs **1520** are for adding and removing dropdown menus and text panes.

The behavior editor **1400** in some embodiments displays the predicate editor **1505** when the user selects an event listed in the events column **1420**. This selection may involve clicking a mouse button or tapping a touchscreen to select the name of the event, selecting an option through keyboard input, etc. For instance, the user may double-click on an event to launch the predicate editor **1505**. The predicate editor **1505** occupies a portion or the entirety of the behavior editor **1400**. The behavior editor may also be a separate window that can be separately manipulated from the behavior editor **1400**.

The behavior editor **1400** in other embodiments provide other means of defining and editing conditions. For instance, the behavior editor **1400** may provide a script editing area for creating and/or editing conditions. However, the behavior editor **1400** in some embodiments provides the predicate editor **1505** in order to make it easier for the user of the platform to author an application. For instance, a user may be able to author applications without getting familiar with writing scripts or without much knowledge in programming.

B. Visually Associating Visual Assets and Non-Visual Assets

FIG. **16** conceptually illustrates a GUI **1600** of the authoring platform of some embodiments. Specifically, this figure illustrates in six different stages **1605-1630** that the GUI allows a user of the platform to associate a behavior having a script response with an entity of a scene being edited. As shown, the GUI **1600** includes a scenes pane **1635**, a scene preview area **1640**, and a behaviors library **1645**.

The scenes pane **1635** in some embodiments is an area of the GUI **1600** that lists the scenes of an application that is being authored by the authoring platform. Scenes may be added to and deleted from the application and the scenes pane **1635** lists different sets of scenes accordingly. The scenes pane **1635** displays the scenes as small thumbnail images with scene names in some embodiments. For instance, the scenes pane **1635** displays scenes **1** and **2** as small thumbnail images showing entities of the scene. The scene **2** thumbnail shows that the scene **2** includes an entity **1636**.

The scene preview area **1640** is similar to the scene preview area **615** described above by reference to FIG. **6**. The scene preview area **1640** displays a scene of the application being built. The user can create or modify the scene by adding or deleting entities (e.g., a graphical icon or an image) to and from the scene preview area **1640**. In some embodiments, the scene preview area **1640** may also display playback of the scene. In addition, the scene preview area **1640** in some embodiments encloses the scene preview area **1640** with a frame that represents a device on which the application would be running. The scene preview area **1640** displays a scene that is selected in the scenes pane **1635**.

The behaviors library **1645** is similar to the behaviors library **620** described above by reference to FIG. **6**. In some embodiments, the GUI **1600** allows the user of the authoring platform to associate an entity and a behavior by dragging a graphical object representing the behavior and dropping it onto an entity displayed in the scene preview area **1640**. When the behavior that is associated with the entity has a script response with a variable that represents an entity or a scene, the GUI **1600** allows the user to graphically link the variable with an entity or a scene. For instance, the "To Scene" behavior includes a script response, which, when executed, causes the application to change the current scene to another scene upon receiving a touchup event on an entity with which "To Scene" behavior is associated.

At the first stage **1605**, the scene preview area is displaying scene **1**. As shown, the scene **1** includes four entities **1641-1644**. The scenes pane **1635** lists scenes **1** and **2**. The behaviors library **1645** lists three behaviors, "Bulge," "Glow," and "To Scene." At the second stage **1610**, the user of the authoring platform selects the "To Scene" behavior. This selection may involve clicking a mouse button or tapping a touchscreen to select a graphical object representing a behavior, selecting an option through keyboard input, etc.

At the third stage **1615**, the user of the authoring platform drags the "To Scene" behavior over the entity **1641**. In some embodiments, as the user moves the cursor while a behavior is selected, the GUI **1600** shows the graphical object (e.g., a gear-looking icon) along the path of the cursor in order to provide a visual cue. When the graphical object hovers near an icon, the GUI may provide another visual cue (e.g., a different background color for the icon) to indicate that the behavior represented by the graphical object will be associated with the icon once the graphical object is dropped there. The user drops the graphical object representing the "To Scene" behavior onto the entity **1641**. As a result, the icon **1641** is associated with the "To Scene" behavior.

At the fourth stage **1620**, the user selects the entity **1641** to view the variables associated with the script response of the "To Scene" behavior. For instance, the user right-clicks the entity **1641** on the scene preview area **1640**. Upon receiving the selection of the entity, the GUI **1600** in some embodiments prompts a drop-down menu **1646** from which the user can select an item representing a variable. The dropdown menu **1646** lists an item for a variable that represents a scene to change to and the user selects it.

At the fifth stage **1625**, upon the user's selection of the item in the menu **1646**, the GUI **1600** displays a bar **1626**. One end of the bar is anchored on the entity **1641**. The GUI **1600** allows the user to extend this bar by dragging the other end of the bar. At the sixth stage **1630**, the user extends the bar **1626** to the scene **2** listed in the scenes pane **1635**. In some embodiments, the GUI provides a visual cue (e.g., a different background color) to indicate that the variable's value is set to the scene **2**.

FIG. **17** conceptually illustrates a device **1700** that runs the application described above by reference to FIG. **16**. Specifically, FIG. **17** illustrates in three different stages **1705-1715** that the application executes the response of the "To Scene" behavior upon receiving a touchup event on the entity **1641**. The device **1700** in some embodiments has a memory (not shown) to store the application and a processor (not shown) to run instructions of the application. The device **1700** also has a display area **1720** that can display scenes of the application. The display area **1720** is capable of detecting user's touch. More details about a device like the device **1700** will be described further below by reference to FIG. **25**.

At the first stage **1705**, the device **1600** is running the application. Specifically, the display area **1720** displays the scene **1** of the application. That is, the display area **1720** displays the four entities **1641-1644**. As mentioned above, the entity **1641** is associated with the "To Scene" behavior. At the second stage **1710**, a user of the application touches the entity with her finger and lifts it up. As the user lifts up her finger, the application receives a touchup event from an operating system that runs on the device **1700**. The application then performs a process such as the process **1200** described above by reference to FIG. **12** to execute the response that is associated with the touchup event. At the third stage **1715**, the application switches to the scene **2** described above by reference to FIG. **16**. Thus, the display area **1720** displays the entity **1636**.

C. Key-Indexed Graphs

FIG. **18** conceptually illustrates a GUI **1800** of the authoring platform of some embodiments. Using the GUI **1800**, a user of the authoring platform builds interactive applications by specifying scenes, entities, and behaviors, etc. As shown in the figure, the GUI **1800** includes a scenes pane **1805**, a scene information pane **1810**, a scene preview area **1820**, an entity properties editor **1830**, a behaviors library **1825**, and a key indices display area **1815**.

The scenes pane **1805** is similar to the scenes pane **1635** described above by reference to FIG. **16**. The scenes pane **1805** in some embodiments is an area of the GUI **1800** that lists the scenes of an application that is being authored by the authoring platform. Scenes may be added to and deleted from the application and the scene pane **1805** lists different sets of scenes accordingly. The scenes pane **1805** displays the scenes as small thumbnail images with scene names in some embodiments. For instance, the scenes pane **1805** displays an example scene **1** as a small thumbnail image showing entities of the scene.

The scene information **1810** displays information about a scene selected in the scenes pane **1805**. For instance, the scene information pane **1810** includes two text panes **1811** and **1812**. In the text pane **1811**, the GUI **1800** displays the name of the selected scene. The GUI **1800** allows the user to type in a desired name should the user want to change the name of the selected scene. In the text pane **1812**, the GUI **1800** displays the description of the selected scene. The user can type in a desired description for the selected scene.

The behaviors library **1825** is similar to the behaviors library **1645** described above by reference to FIG. **16**. The behaviors library **1825** displays a list of behaviors that are represented as graphical objects. For instance, the behaviors library **1825** display a gear-looking icon next to the name of a behavior. In some embodiments, the behaviors library **1825** displays predefined behaviors.

The scene preview area **1820** is similar to the scene preview area **1640** described above by reference to FIG. **16**. The scene preview area **1820** displays a scene of the application being built by the authoring platform. The user can modify the scene by adding or deleting entities (e.g., a graphical icon or an image) to and from the scene preview area **1820**. The scene preview area **1820** displays a scene that is selected in the scenes pane **1805**. For instance, the scene preview area **1820** displays entities **1821**-**1823** of the scene **1** that is currently selected in the scenes pane **1805**. In some embodiments, the scene preview area **1820** may also display playback of the scene. That is, the GUI **1800** can simulate the execution of the application being built within the scene preview area **1820**.

The scene preview area **1820** in some embodiments encloses the scene preview area **1820** with a frame that represents the appearance of a device on which the application would be running. In some embodiments, the GUI **1800** provides different frames for different devices so that the user can replace the frame enclosing the scene preview area **1820** with another frame of another device. Also, the GUI **1800** allows the user to change the orientation (e.g., portrait or landscape) of the scene preview area **1820**.

In some embodiments, the GUI **1800** allows the user to associate an entity displayed in the scene preview area **1820** and a behavior in the behaviors library **1825** by dragging a graphical object representing the behavior and dropping it onto the entity. When the behavior that is associated with the entity has a script response with a variable that represents an entity or a scene, the GUI **1800** allows the user to graphically link the variable with an entity or a scene. An example of such graphical linking is described above by reference to FIG. **16**.

The key indices display area **1815** is similar to the key indices display area **820** described above by reference to FIG. **8**. The key indices display area **1815** displays a key-indexed graph for each of the entities of the scene that is selected in the scenes pane **1805**. For instance, the key indices display area **1815** is displaying three key-indexed graphs **1816**-**1818** for the entities **1821**-**1823**, respectively, of the scene **1**. The names of the entities **1821**-**1823** are “Icon **1**,” “Icon **2**,” and “Icon **3**,” respectively.

The key indices display area **1815** includes a time code line **1842** for indicating duration of each key-indexed graph and temporal positions of key indices along the key-indexed graphs **1816**-**1818**. For instance, each of the key-indexed graph **1816**-**1818** has a duration of a second. The key index handle **1819** is placed on the key-indexed graph **1816** around 0.6 second.

In some embodiments, the GUI **1800** allows the user of the authoring platform to place handles for key indices on the key-indexed graph. As mentioned above, a pair of key indices on a key-indexed graph represents a start and an end of an animation for an entity (e.g., an icon) of a scene. Different embodiments have different ways of adding handles for key indices. For instance, the GUI **1800** of some embodiments provides a playhead **1841**. The user can move the playhead **1841** horizontally along the key-indexed graph to select a position to add a handle. The user can add a handle for a key index by selecting a position along the key-indexed graph and then moving the corresponding entity to a new location within the scene preview area **1820**. Once the user moves the entity, a handle will appear at the selected position on the key-indexed graph. Instead of moving the corresponding entity to a new location in the scene preview area, the user can also enter different values for properties of the entity in the entity properties editor **1830**. That is, the user can first select a position along the key-indexed graph with the playhead **1841** and then type in the position values (e.g., coordinates values) for the entity displayed in the scene preview area **1820**. As different values are entered, a handle will appear at the selected position on the key-indexed graph.

In some embodiments, the playhead **1841** moves along the key-indexed graph as the selected scene is played back in the scene preview area **1820**. The 8UI in some embodiments provides a playback control buttons **1824** for the user to control the playback of the selected scene.

The entity properties editor **1830** includes a group of text panes in which the user can type in numerical values to modify each property of an entity. For instance, three text panes **1831**-**1833** are for x, y, and z coordinates of an entity displayed in the scene display area **1820**. In some embodiments, the GUI allows the user to edit the properties of the entity at a key index. The user can select a key index and modify the property values using the entity properties editor **1830**.

FIG. **19** illustrates the GUI **1800** of FIG. **18**, except the key indices display area **1815** displays sub-key-indexed graphs for the properties of the entity **1821**. Not all of sub-key-indexed graphs for the properties are depicted in this figure for simplicity of description. By providing a sub-key-indexed graph for each of the properties of an entity, the GUI **1800** allows the user to control each property of the entity by adding and editing key indices to the sub-key-indexed graph.

The GUI **1800** in some embodiments allows the user to expand a key-indexed graph for an entity by selecting the key-indexed graph for the entity. This selection may involve clicking a mouse button or tapping a touchscreen to select the key-indexed graph, selecting an option through keyboard input, etc. For instance, the user may click on an expansion indicator **1840** to cause the key indices display area **1815** to display sub-key-indexed graphs for the properties of the entity **1821**. The properties of an entity in some embodiments include a position, a scale, a rotation, a color, etc. to name a few.

In some embodiments, the GUI **1800** allows the user of the authoring platform to place handles for key indices on the sub-key-indexed graphs in a similar manner to add key indices to the key-indexed graphs for the entities. For instance, the user can add a handle for a key index on the sub-key-indexed graph **1905** which is for the size property of the entity **1821**. The user can first select a position along the sub-key-indexed graph **1305** with the playhead **1841** and then specify a desired size (e.g., by grabbing an edge and stretching/shrinking) of the icon **1821** in the scene preview area **1820**. A new handle for a key index will appear on the selected position. When the scene is played back, the size of the entity **1821** will gradually stretch or shrink to the desired size at the time specified by the handle for the key index. In a similar manner, the user can add handles for key indices to other sub-key-indexed graphs for other properties of the entity **1821**.

Having described several GUI tools for editing an authored application, the next Section III will now describe merging responses using some of those GUI tools.

III. Merging Responses

FIG. **20** conceptually illustrates a process **2000** that some embodiments perform to manage a key indices display area. Specifically, some embodiments perform the process **2000** in order to combine several responses in the key-indexed graphs displayed in the key indices display area. In some embodiments, the process **2000** is performed by a GUI of the authoring platform of some embodiments such as the GUI **1800**. The process **2000** will be described with reference to FIG. **21**. FIG. **21** illustrates in five different stages **2105**-**2125** merging two different animation responses of two different behaviors in the sub-key-indexed graphs of the GUI **1800** described above by reference to FIG. **18**. FIG. **21** illustrates the GUI **1800** of FIG. **18**, except that FIG. **21** does not illustrate all components of the GUI **1800** for the simplicity of description.

The process **2000** begins by receiving (at **2005**) a user input regarding the key indices display area. The user input may be selecting a scene to cause the key indices display area to display the entities of the scene, expanding a key-indexed graph into sub-key-indexed graphs, adding/deleting/moving handles from key-indexed graphs, dropping of a behavior onto a key indices display area, etc. At the first stage **2105** of FIG. **21**, the user has selected the scene **1** and expanded the key-indexed graph for the entity **1821** into the sub-key-indexed graphs for the properties of the entity **1821**. As described above, the entity **1821** is an icon named "Icon **1**."

Next, the process **2000** determines (at **2010**) whether the process has received a behavior into the key-indexed graph. The process **2000** in some embodiments determines that it has received a behavior when the user drags and drops a graphical object representing the behavior into the key-indexed graph. At the second stage **2110** of FIG. **21**, the user has selected and dragged "Bulge" behavior over the key indices display area **1815** near the sub-key-indexed graphs for the entity **1821** and dropped it. In this example, the "Bulge" behavior includes an animation response with the same name "Bulge." This animation response, when executed, changes the size of the entity associated with the "Bulge" behavior by enlarging the entity. As mentioned above, an animation response may include a set of key indices. Since the "Bulge" response will cause the entity to change the size, this response has one or more key indices on the sub-key-indexed graph for the size property of the entity.

Returning to FIG. **20**, when the process **2000** determines (at **2010**) that the process has not received a behavior, the process proceeds to **2015** to display the key-indexed graphs in the key indices display area according to the received action. For instance, the process will display the key-indexed graphs for entities of a different scene when the user has selected a different scene to edit.

When the process **2000** determines (at **2010**) that the process has received a behavior, the process determines (at **2020**) whether it is necessary to change the key-indexed graphs. The process **2000** in some embodiments determines that key-indexed graph changes are necessary when the received response requires to place key indices in the key-indexed graphs. For instance, when the received response is an animation response, the process determines that key-indexed graph changes are necessary. Also, when the received response is a type of response other than an animation response but still requires placing key indices in the key-indexed graphs, the process determines that key-indexed graph changes are necessary. For instance, a script response written in such a way that results in animating the entity would require to place key indices in the key-indexed graph.

When the process **2000** determines (at **2020**) that the received response does not require to change the key-indexed graph, the process **2000** proceeds to **2025** to notify the user that the behavior that was brought into the key-indexed graph does not require key-indexed graph changes. Different embodiments notify the user differently. For instance, the process **2000** in some embodiments prompts a message indicating that the received behavior does not require key-indexed graph changes.

When the process **2000** determines (at **2020**) that the received behavior requires key-indexed graph changes, the process determines (at **2030**) whether the received behavior is the first behavior that the key-indexed graphs have received. When the process determines (at **2030**) that the received behavior is the first behavior that is brought into the time display area, the process displays (at **2035**) the response of the behavior that requires key-indexed graphs changes. The process displays the response by placing the key indices of the response in the appropriate key-indexed graphs or sub-key-indexed graphs.

For instance, at the third stage **2115** of FIG. **21**, the "Bulge" behavior is the first behavior that was brought into the key indices display area for the entity **1821**'s sub-key-indexed graphs. The "Bulge" response of the "Bulge" behavior has one key index for the size property of the entity **1821**. Accordingly, a handle **2155** for the one key index is placed on sub-key-indexed graph **2160** as shown. In some embodiments, the key indices display area **1815** switches to a different view when it displays key indices for a response. This view is for displaying the key-indexed graphs and sub-key-indexed graphs for the duration of the response only. That is, the beginning of each sub-key-indexed graph represents the moment that the entity receives the event associated with the response, not the beginning of a scene. In some embodiments, the key indices display area **1815** provides a visual cue to indicate that the key indices display area **1815** is displaying a response, not a scene. For instance, the key indices display area **1815** may display texts saying that the key indices display area **1815** is displaying a response or may use different background colors.

Returning to FIG. **20**, when the process **2000** determines (at **2030**) that the received behavior is not the first behavior received (i.e., that the key indices display area is already displaying one or more responses), the process **2000** determines (at **2040**) whether the response of the behavior just received and the responses that are already displayed in the key indices display area are associated with the same event. When the process **2000** determines (at **2040**) that these responses are not associated with the same event, the process **2000** proceeds to **2045** to notify the user that these responses are not associated with the same event and therefore cannot be merged.

At the fourth stage **2120** of FIG. **21**, the user has selected and dragged "Fade" behavior over the key indices display area **1815**, which is displaying "Bulge" response of the "Bulge" behavior. In this example, the "Fade" behavior includes an animation response with the same name "Fade." This animation response, when executed, changes the opacity of the entity associated with the "Fade" behavior such that the entity appears to be fading. Since the "Fade" response will cause the entity to change the opacity only, this response has one or more key indices on the sub-key-indexed graph for the opacity property of the entity.

When the process **2000** determines (at **2040**) the response just brought in and the responses displayed in the key indices display area are associated with the same event, the process **2000** then determines (at **2050**) whether there are conflicts to resolve with regards to placing the key indices of the response just brought in. That is, a key index of that response may be for the sub-key-indexed graph that already has other key indices placed or may even overlap with another existing key index. The process **2000** would have to determine what to do with the key indices. When the process **2000** determines (at **2050**) that there are no conflicts to resolve, the process **2000** proceeds to **2055** and place the key indices of the response just brought in at the appropriate positions along the key-indexed graphs or sub-key-indexed graphs.

At the fifth stage **2125** of FIG. **21**, the "Fade" behavior is not the first behavior that was brought into the key indices display area **1815** for the entity **1821**'s sub-key-indexed graphs. The "Fade" response of the "Fade" behavior has one key index for the opacity property of the entity **1821**. Moreover, there is no existing key index in sub-key-indexed graph **2170** for the opacity property of the entity **1821**. Accordingly, a handle **2165** for the one key index is placed on the sub-key-indexed graph **2170** as shown.

When the process **2000** determines (at **2050**) that there are conflicts to resolve, the process **2000** proceeds to **2060** to resolve the conflicts. For instance, when a particular key index of the response just brought in overlaps with an existing key index, the process **2000** in some embodiments may (1) keep only the existing key index in the key-indexed graph, (2) place the particular key index in the key-indexed graph and remove the existing key index from the key-indexed graph, or (3) composite the two key indices (e.g., by taking a mean of the values represented by the two key indices). When the particular key index and existing key indices fall in the same key-indexed graph, the authoring platform of different embodiments may (1) keep the existing key indices only, (2) keep the key indices of the response being dropped, or (3) keep all of the key indices in the key-indexed graph. The process **2000** then ends.

## IV. Automatically Detecting Boundaries

As mentioned above, the authoring platform of some embodiments is used by application developers to develop applications that run on devices. In order for the developed applications function properly, the applications have to meet the specifications of the devices. For instance, the scenes of an application would have to meet the specifications for the output video of a device. For example, a device may output its video as a rectangular shape with certain height, width, corner roundness, etc., and a scene's height, width, corner roundness, etc. have to match those of the output video of the device.

In some cases, the device manufacturers provide the application developers with the output video specifications during an initial phase of designing the devices so that application developers can develop the applications to run on the devices in parallel. However, it is often the case that the output video specifications for the devices get changed before the manufacturer finalizes the design of the device. Also, the manufacturers may change the video output specifications for the devices for the next versions of the devices. In such cases, the applications developers may have to comply with the changes to the video output specifications in order to ensure the proper functioning or rendering of the scenes of the applications. Complying with those changes may involve performing substantial and resource-consuming tasks.

The authoring platform of some embodiments enables the applications being authored to detect some of the video output specifications automatically so that the developers do not have to modify their applications to comply with changes to those video output specifications. In particular, the applications authored by the authoring platform will automatically detect boundaries of a transparent area in an image provided by a device manufacturer. In some embodiments, the boundaries of the transparent area of the image serve as a video output specification of a device that the device manufacturer makes. For instance, the device is designed to output its video as a rectangular shape with certain height, width, corner roundness, etc., and the manufacturer conveys this dimensional information to the applications developers as a rectangular image with a transparent area having the certain height, width, corner roundness, etc. In some embodiments, an image provided by the manufacturer is in a format that supports transparency. For instance, some embodiments use a Portable Network Graphics (.png) or a Tagged Image File Format (.tiff).

FIG. **22** conceptually illustrates a process **2200** that some embodiments performs to detect boundaries of a transparent area within an image. The process **2200** in some embodiments is performed by an authoring platform when a user of the authoring platform creates a scene for the application that is being authored by the authoring platform. The process **2200** may also be performed by an application that is authored by the authoring platform of some embodiments when it renders a scene while the application executes. The process **2200** will be described by reference to FIG. **23**. FIG. **23** conceptually illustrates in four different stages finding boundaries of a transparent area within an image.

The process **2200** begins by receiving (at **2205**) an image on top of which a scene of the authored application is to be rendered. In some embodiments, the process assumes that the boundaries of the transparent area within the image form a shape that is of the same type but smaller than the shape of the received image. For instance, when the received image is rectangular, the process would find a smaller rectangular shape formed by the transparent area within the received shape.

In some embodiments, the image is in a format (e.g., .png format) that supports transparency. As mentioned above, a pixel of an image in such format can have an alpha value, which, as known in the art, is a value that specifies opacity of the pixel. An alpha value of zero means that the pixel is completely transparent. When a complete transparent pixel is composited with another pixel, the composite pixel will be displayed as if that other pixel alone is displayed. An alpha value of one means the pixel is completely non-transparent.

Therefore, a pixel supports transparency when the pixel has an alpha value (e.g., between 0 and 1). In some cases, not all pixels of an image support transparency.

The first stage **2305** of FIG. **23** shows a rectangular transparent area **2325** within an image **2330**. The image **2330** is in a format (e.g., .png format) that supports transparency. Every pixel within the transparent area **2330** has an alpha value of zero. Every pixel in an area **2335** that is outside the transparent area **2325** and inside the image **2330** does not have an alpha value.

Next, the process **2200** identifies (at **2210**) the center pixel of the received image. Different embodiments identify the center pixel of the received image differently. For instance, in some embodiments, the process identifies the center pixel by computing the geometric center of the shape that the received image forms. The process then identifies a pixel that is nearest to the geometric center as the center pixel of the image. In other embodiments, the process assigns coordinate values in two-dimensional space (e.g., x and y coordinate values) to each pixel of the image and takes an average (e.g., arithmetic mean) of the values assigned to all pixels of the image. In these embodiments, the process will identify the image with coordinate values that are closest to the average coordinate values. The second stage **2310** of FIG. **23** shows a center pixel **2340** of the image **2330** depicted as an x mark. As mentioned above, the center pixel **2340** has an alpha value.

The process **2200** then determines (at **2215**) whether the center pixel of the received image supports transparency. In some embodiments, the process **2200** determines that the center pixel of the received image supports transparency when the center pixel has an alpha value that is less than a certain threshold value that is less than 1.0. For instance, when the center pixel has an alpha value of 0.5 or less, the process **2200** in some embodiments determines that the center pixel supports transparency. When the process **2200** determines (at **2215**) that the center pixel does not support transparency, the process ends.

When the process **2200** determines (at **2215**) that the center pixel supports transparency, the process in some embodiments proceeds to **2220** to select a direction from the center pixel. As mentioned above, the process in some embodiments assumes that the type of shape that the received image forms is the type of shape that the transparent area forms. The process selects a direction based on the type of shape that the transparent area would form. For instance, when the received image is rectangular, the process would select one of four perpendicular directions to find the four edges of the rectangular shape that the transparent area would form within the received image. The third stage **2315** of FIG. **23** shows four perpendicular directions **2345**, **2350**, **2355**, and **2360** depicted as arrows pointing away from the center pixel **2340**.

Next, the process **2200** selects (at **2225**) the next pixel in the selected direction. The process **2200** then determines (at **2230**) whether the selected pixel supports transparency. When the process **2200** determines (at **2230**) that the selected pixel does not support transparency, the process **2200** loops back to **2225** to select the pixel that is next to the currently selected pixel in the selected direction. When the process **2200** determines (at **2230**) that the selected pixel does not support transparency, the process **2200** sets (at **2235**) the selected pixel as a boundary pixel, which the process will use to draw a boundary. Next, the process **2200** determines (at **2240**) whether there are more directions from the center pixel in which to examine pixels to find boundaries. When the process **2200** determines (at **2240**) that there are more directions in which to examine pixels to find boundaries, the process loops back to **2220** to select another direction. The third stage **2315** of FIG. **23** shows four pixels **2365**, **2370**, **2375**, and **2380** depicted as hollow circles. The pixels **2365-2380** are the first pixels that do not have an alpha value in the directions **2345-2360**, respectively.

When the process **2200** determines (at **2240**) that there are no more directions in which to examine pixels to find boundaries, the process **2200** proceeds to **2245** to draw boundaries based on the boundary pixels set at **2235**. For instance, the process **2200** would draw a rectangular shape based on the four boundary pixels that the process would have set at **2235**. The fourth stage **2320** of FIG. **23** shows a rectangular shape drawn based on the pixels **2365-2380**. The process **2200** identifies the pixels forming the drawn boundaries as pixels that define the boundaries of the transparent area.

The specific operations of the process **2200** may not be performed in the exact order shown and described. The specific operations may not be performed in one continuous series of operations, and different specific operations may be performed in different embodiments. Furthermore, the process could be implemented using several sub-processes, or as part of a larger macro process. For instance, the process **2200** does not have to find and set a boundary pixel for one selected direction at a time. Moreover, the process **2200** is described in the context of having received a rectangular image. However, one of the ordinary skill in the art will realize that the process **2200** would be applicable for finding boundaries of other types of shapes (e.g., a triangular shape, an pentagonal shape, and other polygonal shapes, etc.).

Also, the process **2200** in some embodiments detects boundaries of a transparent area by expanding the boundaries from the determined center pixel in certain directions. Alternatively, or conjunctively, the process in some embodiments expands the boundaries by recursively examining all neighboring pixels of the already examined pixels. That is, the process may examine the neighboring pixels of the determined center pixel to see whether the neighboring pixels are transparent and then include those pixels within the boundaries. The process repeats these operations until all contiguous transparent pixels are included within the expanding boundaries. Moreover, the process in some embodiments may not expand the boundaries from the determined center pixel. For instance, the process may select a pixel from the received image, determine whether the pixel supports transparency and is transparent, and then expand the boundaries of the transparent area from that pixel.

## V. Authoring Platform Architecture

FIG. **24** illustrates the software architecture of an authoring platform **2400** for building applications. As shown, the authoring platform of some embodiments includes a user interface **2405**, an event definer **2410**, a conditions definer **2411**, a response definer **2415**, a condition-event associator **2420**, an event-response associator **2425**, an entity-behavior associator **2430**, an entity-scene associator **2435**, a key-indexed graph manager **2440**, a key indices manager **2445**, a scene preview area manager **2450**, a boundary detector **2455**, and a transparency checker **2460**. The authoring platform also includes a conditions repository **2465**, an events repository **2470**, a responses repository **2475**, a behaviors repository **2480**, an entities repository **2485**, a scenes repository **2490**, and a scene templates repository **2495**, and a build application repository **2499**.

The authoring platform **2400** provides the user with the user interface **2405** through which the user can input data for authoring the application. The user interface **2405** is similar to the user interface **205** of FIG. **2**. Through the user interface **2405**, the user can specify events and responses and associate the events and responses. In addition, the user also can specify conditions for an event to trigger responses associated with the event. The user can also specify entities for scenes of an interactive application. The user interface **2405** sends the received input data to other modules of the authoring platform **2400**. For instance, the user interface **2405** sends the received data to the event definer **2410** and the response definer **2415**.

The event definer **2410** defines events based on the received data. The event definer **2410** is similar to the event definer **210** of FIG. **2**, in that the event definer **2410** creates an event based on the received data. For instance, based on the received data, the event definer creates an event that encapsulates an application user's touching multiple locations of a scene. The event definer **2410** stores the defined events in the events repository **2470**, which is a cache or other persistent storage medium in some embodiments.

The conditions definer **2411** defines conditions based on the received data. The user of the authoring platform specifies conditions through the user interface **2405**. For instance, the user interface may provide the predicate editor **1505** of Figure Q. As described above, conditions are associated with an event such that the event can trigger responses only if the conditions associated with the event are satisfied when the authored application is running. Conditions can be added to a predefined event or an event defined by the authoring platform user. As mentioned above, the authoring platform **2400** in some embodiments provides predefined events. Examples of pre-defined events include a touchdown event, a touchup event, etc. The conditions definer **2412** stores the defined conditions in the conditions repository **2465**, which is a cache or other persistent storage medium in some embodiments.

The response definer **2415** is similar to the response definer **215** of FIG. **2** in that the response definer **2415** defines different types responses based on the received data and defines response handlers for these different types of responses. The response definer **2415** stores defined responses and response handlers in the responses repository **2475**, which is cache or other persistent storage medium in some embodiments. In addition, similar to the response definer **215**, the response definer **2415** uses the conformance manager **2416** to define different types of responses in such a way that the responses of different types can communicate with each other. Moreover, in some embodiments, the authoring platform **2400** includes the response definer **2415** for each of the different types of responses so that each response definer **2415** defines response(s) of one type.

The condition-event associator **2420** associates an event with one or more conditions based on the received data. For instance, the condition-event associator **2420** associates a condition that the user specified through the predicate editor **1505** of Figure Q with a touchdown event. The condition-event associator **2420** stores data specifying associations of events and conditions either in the conditions repository **2465** or in the events repository **2470**. That is, in some embodiments a condition may have a reference to the event with which the condition is associated. An event may also have references to conditions with which the event is associated. Or, both events and conditions have references to each other.

The event-response associator **2425** is similar to the event-response associator **230** in that the event-response defines behaviors by associating each event with one or more responses based on the received data. As mentioned above, an event may be associated with responses of different types. The event-response associator **2425** stores defined behaviors in the behaviors repository **2480**, which is cache or other persistent storage medium in some embodiments.

The entity-behavior associator **2435** is similar to the entity-behavior associator **240** of Figure A in that the entity-behavior associator **2435** associates an entity with one or more behaviors per user's specification. As mentioned above, entities are graphical objects

The entity-behavior associator **2435** of some embodiments stores the associations of behaviors and entities in the entities repository **2485**, which is a cache or other persistent storage medium in some embodiments. In some embodiments, an entity has references to the behaviors that are associated with the entity. A behavior may have references to entities that are associated with the behavior. In some embodiments, one behavior may be associated with one or more entities.

The entity-scene associator **2435** associates entities with scenes. For instance, when a user drops an entity on a scene through the user interface **2405**, the entity-scene associator **2435** associates the entity with the scene. The entity-scene associator **2435** stores data specifying associations of entities and scenes either in the entities repository **2485** or in the scenes repository **2490**. That is, in some embodiments an entity may have a reference to the scene that is associated with the entity. The scene may also have references to entities that are associated with the scene. Or, both entities and scenes may have references to each other. The scenes repository **2490**, which is a cache or other persistent storage medium in some embodiments, stores scenes that may become part of authored applications. The authored applications are stored in the authored applications repository **2499**, which is cache or other persistent storage medium in some embodiments.

The key-indexed graph manager **2440** manages key-indexed graphs for entities of scenes. The key-indexed graph manager **2440** receives user inputs through the user interface **2405** and creates and/or modifies key-indexed graphs for the entities of the scenes. The key-indexed graph manager **2440** retrieves scenes from the scenes repository **2490**. The key-indexed graph manager **2440** also uses the key indices manager **2445** to create and/or modify key indices for the entities of the scenes.

The scenes manager **2450** manages scenes. The scenes manager **2450** creates and/or modifies scenes based on the user's inputs. For instance, the scenes manager **2450** creates a scene with a scene template that the user has chosen. The scene templates in some embodiments are images provided by a manufacturer of a device on which an application authored by the authoring platform **2400** would execute. As described above, such images support transparency. The scene templates may be stored in the scene templates repository **2495**, which is a cache or other persistent storage medium in some embodiments. The scenes manager **2450** in some embodiments uses the boundary detector **2455** to identify boundaries of transparent areas within the scene templates. The boundary detector **2455** in some embodiments uses the transparency checker **2460** to determine whether pixels of the scene templates support transparency. As mentioned above, a pixel with an alpha value supports transparency.

VI. Electronic Systems

Many of the above-described features and applications are implemented as software processes that are specified as a set of instructions recorded on a computer readable storage medium (also referred to as computer readable medium). When these instructions are executed by one or more computational or processing unit(s) (e.g., one or more processors, cores of processors, or other processing units), they cause the processing unit(s) to perform the actions indicated in the instructions. Examples of computer readable media include, but are not limited to, CD-ROMs, flash drives, random access memory (RAM) chips, hard drives, erasable programmable read only memories (EPROMs), electrically erasable programmable read-only memories (EEPROMs), etc. The computer readable media does not include carrier waves and electronic signals passing wirelessly or over wired connections.

In this specification, the term “software” is meant to include firmware residing in read-only memory or applications stored in magnetic storage which can be read into memory for processing by a processor. Also, in some embodiments, multiple software inventions can be implemented as sub-parts of a larger program while remaining distinct software inventions. In some embodiments, multiple software inventions can also be implemented as separate programs. Finally, any combination of separate programs that together implement a software invention described here is within the scope of the invention. In some embodiments, the software programs, when installed to operate on one or more electronic systems, define one or more specific machine implementations that execute and perform the operations of the software programs.

FIG. **25** conceptually illustrates an electronic system **2500** with which some embodiments of the invention are implemented. The electronic system **2500** may be a computer (e.g., a desktop computer, personal computer, tablet computer, etc.), phone, PDA, or any other sort of electronic device. Such an electronic system includes various types of computer readable media and interfaces for various other types of computer readable media. Electronic system **2500** includes a bus **2505**, processing unit(s) **2510**, a graphics processing unit (GPU) **2515**, a system memory **2520**, a network **2525**, a read-only memory **2530**, a permanent storage device **2535**, input devices **2540**, and output devices **2545**.

The bus **2505** collectively represents all system, peripheral, and chipset buses that communicatively connect the numerous internal devices of the electronic system **2500**. For instance, the bus **2505** communicatively connects the processing unit(s) **2510** with the read-only memory **2530**, the GPU **2515**, the system memory **2520**, and the permanent storage device **2535**.

From these various memory units, the processing unit(s) **2510** retrieves instructions to execute and data to process in order to execute the processes of the invention. The processing unit(s) may be a single processor or a multi-core processor in different embodiments. Some instructions are passed to and executed by the GPU **2515**. The GPU **2515** can offload various computations or complement the image processing provided by the processing unit(s) **2510**. In some embodiments, such functionality can be provided using CoreImage’s kernel shading language.

The read-only-memory (ROM) **2530** stores static data and instructions that are needed by the processing unit(s) **2510** and other modules of the electronic system. The permanent storage device **2535**, on the other hand, is a read-and-write memory device. This device is a non-volatile memory unit that stores instructions and data even when the electronic system **2500** is off. Some embodiments of the invention use a mass-storage device (such as a magnetic or optical disk and its corresponding disk drive) as the permanent storage device **2535**.

Other embodiments use a removable storage device (such as a floppy disk, flash memory device, etc., and its corresponding disk drive) as the permanent storage device. Like the permanent storage device **2535**, the system memory **2520** is a read-and-write memory device. However, unlike storage device **2535**, the system memory **2520** is a volatile read-and-write memory, such as random access memory. The system memory **2520** stores some of the instructions and data that the processor needs at runtime. In some embodiments, the invention’s processes are stored in the system memory **2520**, the permanent storage device **2535**, and/or the read-only memory **2530**. For example, the various memory units include instructions for processing multimedia clips in accordance with some embodiments. From these various memory units, the processing unit(s) **2510** retrieves instructions to execute and data to process in order to execute the processes of some embodiments.

The bus **2505** also connects to the input and output devices **2540** and **2545**. The input devices **2540** enable the user to communicate information and select commands to the electronic system. The input devices **2540** include alphanumeric keyboards and pointing devices (also called “cursor control devices”), cameras (e.g., webcams), microphones or similar devices for receiving voice commands, etc. The output devices **2545** display images generated by the electronic system or otherwise output data. The output devices **2545** include printers and display devices, such as cathode ray tubes (CRT) or liquid crystal displays (LCD), as well as speakers or similar audio output devices. Some embodiments include devices such as a touchscreen that function as both input and output devices.

The present application describes a graphical user interface that provides users with numerous ways to perform different sets of operations and functionalities. In some embodiments, these operations and functionalities are performed based on different commands that are received from users through different input devices (e.g., keyboard, trackpad, touchpad, mouse, etc.). For example, the present application illustrates the use of a cursor in the graphical user interface to control (e.g., select, move) objects in the graphical user interface. However, in some embodiments, objects in the graphical user interface can also be controlled or manipulated through other controls, such as touch control. In some embodiments, touch control is implemented through an input device that can detect the presence and location of touch on a display of the device. An example of such a device is a touch screen device. In some embodiments, with touch control, a user can directly manipulate objects by interacting with the graphical user interface that is displayed on the display of the touch screen device. For instance, a user can select a particular object in the graphical user interface by simply touching that particular object on the display of the touch screen device. As such, when touch control is utilized, a cursor may not even be provided for enabling selection of an object of a graphical user interface in some embodiments. However, when a cursor is provided in a graphical user interface, touch control can be used to control the cursor in some embodiments.

Finally, as shown in FIG. **25**, bus **2505** also couples electronic system **2500** to a network **2525** through a network adapter (not shown). In this manner, the computer can be a part of a network of computers (such as a local area network (“LAN”), a wide area network (“WAN”), or an Intranet, or a network of networks, such as the Internet. Any or all components of electronic system **2500** may be used in conjunction with the invention.

Some embodiments include electronic components, such as microprocessors, storage and memory that store computer program instructions in a machine-readable or computer-readable medium (alternatively referred to as computer-readable storage media, machine-readable media, or machine-readable storage media). Some examples of such computer-readable media include RAM, ROM, read-only compact discs (CD-ROM), recordable compact discs (CD-R), rewritable compact discs (CD-RW), read-only digital versatile discs (e.g., DVD-ROM, dual-layer DVD-ROM), a variety of recordable/rewritable DVDs (e.g., DVD-RAM, DVD-RW, DVD+RW, etc.), flash memory (e.g., SD cards, mini-SD cards, micro-SD cards, etc.), magnetic and/or solid state hard drives, read-only and recordable Blu-Ray® discs, ultra density optical discs, any other optical or magnetic media, and floppy disks. The computer-readable media may store a computer program that is executable by at least one processing unit and includes sets of instructions for performing various operations. Examples of computer programs or computer code include machine code, such as is produced by a compiler, and files including higher-level code that are executed by a computer, an electronic component, or a microprocessor using an interpreter.

While the above discussion primarily refers to microprocessor or multi-core processors that execute software, some embodiments are performed by one or more integrated circuits, such as application specific integrated circuits (ASICs) or field programmable gate arrays (FPGAs). In some embodiments, such integrated circuits execute instructions that are stored on the circuit itself. In addition, some embodiments execute software stored in programmable logic devices (PLDs), ROM, or RAM devices.

As used in this specification and any claims of this application, the terms “computer”, “server”, “processor”, and “memory” all refer to electronic or other technological devices. These terms exclude people or groups of people. For the purposes of the specification, the terms display or displaying means displaying on an electronic device. As used in this specification and any claims of this application, the terms “computer readable medium,” “computer readable media,” and “machine readable medium” are entirely restricted to tangible, physical objects that store information in a form that is readable by a computer. These terms exclude any wireless signals, wired download signals, and any other ephemeral signals.

While the invention has been described with reference to numerous specific details, one of ordinary skill in the art will recognize that the invention can be embodied in other specific forms without departing from the spirit of the invention. In addition, a number of the figures (including FIGS. **4**, **12**, **13**, **13**, **20**, and **22**) conceptually illustrate processes. The specific operations of these processes may not be performed in the exact order shown and described. The specific operations may not be performed in one continuous series of operations, and different specific operations may be performed in different embodiments. Furthermore, the process could be implemented using several sub-processes, or as part of a larger macro process. Thus, one of ordinary skill in the art would understand that the invention is not to be limited by the foregoing illustrative details, but rather is to be defined by the appended claims.

What is claimed is:

**1**. An authoring system for building an application having a set of graphical objects, the authoring system comprising:

a computer processor; and

a memory containing instructions that, when executed, cause the computer processor to:

receive a first input defining a first operation that is to be performed on a first graphical object of the application, wherein the first operation, when performed, results in a first output in a first format;

receive a second input defining a second operation that is to be performed on a second graphical object of the application, wherein:

the second operation is different than the first operation, and

the second operation requires input parameters in a second format, different than the first format, to perform the second operation;

receive a third input involving a user gesture of dragging and dropping the first graphical object onto the second graphical object, thereby automatically associating the first operation performed on the first graphical object with the second operation performed on the second graphical object; and

generate the application such that the second operation is performed according to the first output of the first operation.

**2**. The authoring system of claim **1**, wherein the instructions further cause the computer processor to:

present a graphical user authoring interface enabling a user to specify inputs to build the application, wherein the first input, second input and third input are received as a result of user interaction with the graphical user authoring interface.

**3**. The authoring system of claim **1**, wherein the first input further defines a first user interaction event, wherein, when the application is executed, detection of the first user interaction event causes performance of the first operation.

**4**. The authoring system of claim **1**, wherein the first operation comprises at least one selected from a group consisting of animating the first graphical object, running a script, executing a compiled code and playing back an audio file.

**5**. The authoring system of claim **1**, wherein the second graphical object is the first graphical object.

**6**. The authoring system of claim **1**, further comprising a conformance module configured to determine that the second format does not match the input parameters and to convert the input parameters in a second format into a conformance protocol and convert the first output in a first format into input parameters in the conformance protocol.

**7**. A computer-implemented method for building an application having a set of graphical objects, the method comprising:

receiving, by a computer processor, a first input defining a first operation that is to be performed on a first graphical object of the application, wherein the first operation, when performed, results in a first output in a first format;

receiving, by the computer processor, a second input defining a second operation that is to be performed on a second graphical object of the application, wherein:

the second operation is different than the first operation, and

the second operation requires input parameters in a second format, different than the first format, to perform the second operation;

receiving, by the computer processor, a third input involving a user gesture of dragging and dropping the first graphical object onto the second graphical object, thereby automatically associating the first operation performed on the first graphical object with the second operation performed on the second graphical object; and

generating, by the computer processor, the application such that the second operation according to the first output of the first operation.

**8**. The computer-implemented method of claim **7**, further comprising:

presenting a graphical user authoring interface enabling a user to specify inputs to build the application, wherein the first input, second input and third input are received as a result of user interaction with the graphical user authoring interface.

**9**. The computer-implemented method of claim **7**, wherein the first input further defines a first user interaction event, wherein, when the application is executed, detection of the first user interaction event causes performance of the first operation.

**10**. The computer-implemented method of claim **7**, wherein the first operation comprises at least one selected from a group consisting of animating the first graphical object, running a script, executing a compiled code and playing back an audio file.

**11**. The computer-implemented method of claim **7**, wherein the second graphical object is the first graphical object.

**12**. The computer-implemented method of claim **7**, further comprising:

determining, using a conformance module, that the second format does not match the input parameters; and

converting the input parameters in a second format into a conformance protocol and convert the first output in a first format into input parameters in the conformance protocol.

**13**. A non-transitory computer-readable medium containing instructions for building an application having a set of graphical objects, the instructions, when executed by a computing device, cause the computing device to:

receive a first input defining a first operation that is to be performed on a first graphical object of the application, wherein the first operation, when performed, results in a first output in a first format;

receive a second input defining a second operation that is to be performed on a second graphical object of the application, wherein:

the second operation is different than the first operation, and

the second operation requires input parameters in a second format, different than the first format, to perform the second operation;

receive a third input involving a user gesture of dragging and dropping the first graphical object onto the second graphical object, thereby automatically associating the first operation performed on the first graphical object with the second operation performed on the second graphical object; and

generate the application such that the second operation according to the first output of the first operation.

**14**. The non-transitory computer-readable medium of claim **13**, wherein the instructions further cause the computing device to:

present a graphical user authoring interface enabling a user to specify inputs to build the application, wherein the first input, second input and third input are received as a result of user interaction with the graphical user authoring interface.

**15**. The non-transitory computer-readable medium of claim **13**, wherein the first input further defines a first user interaction event, wherein, when the application is executed, detection of the first user interaction event causes performance of the first operation.

**16**. The non-transitory computer-readable medium of claim **13**, wherein the first operation comprises at least one selected from a group consisting of animating the first graphical object, running a script, executing a compiled code and playing back an audio file.

**17**. The non-transitory computer-readable medium of claim **13**, wherein the second graphical object is the first graphical object.

**18**. The non-transitory computer-readable medium of claim **13**, wherein the instructions further cause the computing device to call a conformance module configured to determine that the second format does not match the input parameters and to convert the input parameters in a second format into a conformance protocol and convert the first output in a first format into input parameters in the conformance protocol.

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